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## GENERAL STRUCTURE OF THE PRODUCING SANDS, IN EASTERN OHIO[1]

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### ABSTRACT

The producing fields of eastern Ohio lie along the west side of the Appalachian syncline where the normal southeast dip is broken by the minor structures which resulted from the Appalachian folding.

The most important structural feature is the broad northern development of the Burning Springs–Volcano anticline which is paralleled on the west by the deep Parkersburg syncline. This general uplift has a width ranging from 25 to 30 miles, and extends about 80 miles northeastward into Ohio from West Virginia.

Twelve shallow sands occur in the Pennsylvanian and Mississippian systems, and two deeper sands have been extensively developed.

The most consistent shallow sand accumulation has been along the general anticlinal structure, and is controlled by local structure, generally lacking any definite trend.

Geological work on the Pennsylvanian and Mississippian sands has been generally successful, but the interpolation of the structure of the deeper sands which lie in the Devonian and Silurian is made more difficult by the rapid eastward expansion of these two systems.

The Cambridge gas sand, which occurs near the base of the Devonian, has been extensively drilled in eastern Guernsey County, where the sharp reversal caused by the Parkersburg syncline is sufficient to overcome the westward convergence of the upper Devonian shales. If this sand is present along the entire length of this uplift, new fields may be discovered in the direction of Parkersburg. East of Guernsey County the dip is too sharp and the convergence too great to be overcome by such reversals as exist.

The Clinton sandstone, near the base of the Silurian, is the deepest producing horizon in eastern Ohio. From a heavy quartzose bed in the extreme eastern part of the state it pinches out to the west into isolated lenses, in the more porous of which the production occurs. This sand is absolutely devoid of water, which feature, together with the lenticular nature of the reservoirs, renders extensive geological work impractical.

[1] Presented before the Association at the Tulsa meeting, March 26, 1927.

[2] The East Ohio Gas Company, 1405 E. Sixth St., Cleveland, Ohio. Introduced by Sidney Powers.

## GENERAL STATEMENT

Structural conditions in parts of eastern Ohio have been described in detail by the state and government surveys,[1] which work has been chiefly for the purpose of ascertaining the possibilities and limitations of geological work in the development of oil and gas and to furnish maps and data which would serve as criteria to those operators who wished to study other areas in a similar way. Although thousands of wells have been drilled, and the entire eastern half of the state studied by geologists, an authentic structure map of the entire area will probably not be available for several years and it has been impossible to publish such connected data as would be of value to those unacquainted with these fields. It is the purpose of this paper to describe the producing sands of eastern Ohio and the structural features influencing accumulation in a general, rather than a local way, giving information which will be of interest to those who contemplate further development in that section.

## GENERAL STRUCTURE AND STRATIGRAPHY

From the crest of the Cincinnati arch in western Ohio the beds dip into the Appalachian trough in Pennsylvania and West Virginia. The axes of both anticline and syncline extend northeast and southwest, but that of the syncline inclines somewhat more to the east. The northern and more shallow part of the trough, therefore, is relatively farther east, and as a result there is practically no east dip across the northeast part of Ohio. In that section of the state the dip is principally to the south, under the influence of the beds which dip southeast into the deeper part of the syncline. The structure of the eastern half of the state is therefore comparable with one quarter of a bowl. The general direction of dip is southeast, and the average rate of dip is 35 feet to the mile.

The beds exposed at the surface in this part of the state are, from west to east, of Mississippian, Pennsylvanian, and Permian age. At least twelve sands occur in the Pennsylvanian and Mississippian, one near the base of the Devonian and one near the base of the Silurian. These horizons will be described more fully in a following section.

[1] W. T. Griswold, "The Berea Grit Oil Sand in the Cadiz Quadrangle, Ohio," *U. S. Geol. Survey Bull. 198*, 1902; "Structure of the Berea Oil Sand in the Flushing Quadrangle," *U. S. Geol. Survey Bull. 346*, 1908. D. D. Condit, "Oil and Gas in the Northern Part of the Cadiz Quadrangle," *U. S. Geol. Survey Bull. 541 A*, 1913. C. A. Bonine, "Anticlines in the Clinton Sand near Wooster, Wayne County, Ohio," *U. S. Geol. Survey Bull. 621 H*, 1915. D. D. Condit, "Structure of the Berea Oil Sand in the Woodsfield Quadrangle," "Structure of the Berea Oil Sand in the Summerfield Quadrangle," *U. S. Geol. Survey Bull. 621 O* and *621 N*, 1916.

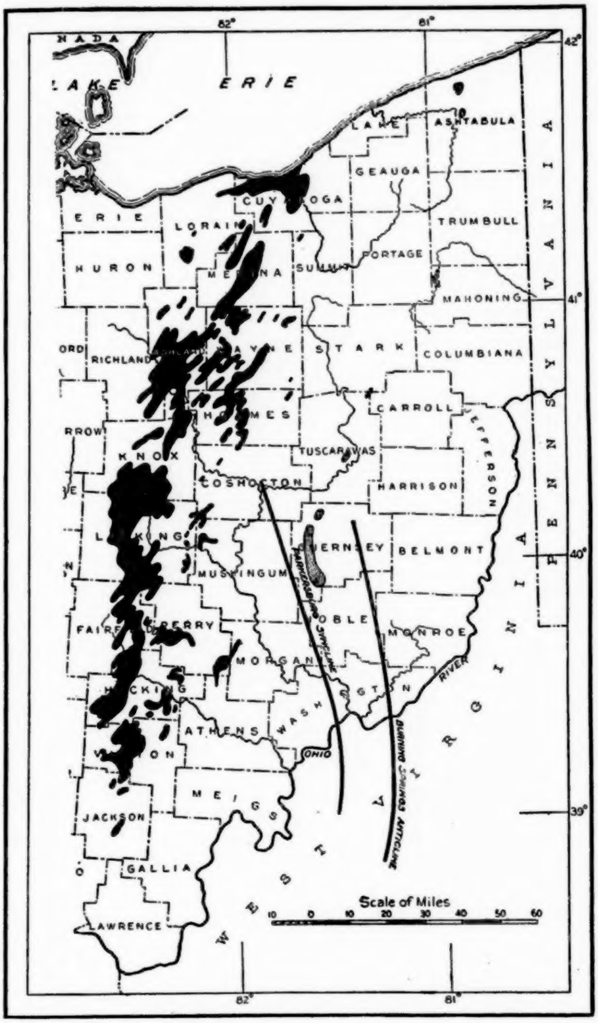


FIG. 1.—Map of eastern Ohio showing the "Clinton sand" fields and the Cambridge gas field in Guernsey County.

The only unconformity of any consequence is that at the base of the Pennsylvanian. Although in some places the relief in the upper Mississippian is as great as 200 feet, the beds above and below this zone lie practically parallel, and the Berea sand, at the base of the Mississippian, conforms reasonably well with the surface structure. The greatest difficulty arising from this unconformity is that of mapping the surface beds along its outcrop from Scioto to Holmes County. The basal members of the Pennsylvanian, including several coals frequently used as reference benches, were deposited in basins in Mississippian topography. Correlation in many places is difficult, and many false structures have been mapped in this area.

The most important factor to be considered in interpolating the structure of beds lying below the top of the Devonian is the rapid eastward expansion of the Devonian and Silurian systems, which comprise the Bedford and Ohio shales of the Upper Devonian and a great series of Devonian and Silurian limestones and dolomites known among operators as "The Big lime." This expansion is given by Stout[1] as 35 feet to the mile to the east, and 0.74 foot to the mile to the south. More recent drilling east of the territory plotted by Stout indicates that the rate of thickening increases in that direction to at least 50 feet to the mile in Harrison and Columbiana counties.

The normal southeast dip is broken by local structures which are the most western results of the Appalachian folding. There are hundreds of low rolling anticlines and shallow synclines which increase in magnitude to the south and east. Many of these structures have been proved to be the controlling factors in shallow sand accumulation, although as many more which looked as promising when mapped have been dry. Owing to the lack of systematic and connected work in any considerable area, the controlling influence of two major structural features has not been recognized. These are the Parkersburg syncline and the Burning Springs–Volcano anticline, which have been mapped by the West Virginia Survey.[2]

The Parkersburg syncline crosses Ohio River between Parkersburg and Marietta and extends northwest at least 80 miles. The axis can be plotted through central Washington County, the southwest and northwest corners of Noble County, the southwestern edge of Guernsey County crossing about the center of the Muskingum-Guernsey county line and extending northwest into central Coshocton County.

[1] Wilbur Stout, *Geol. Survey of Ohio, Bull. 21* (1918), pp. 287–88.

[2] G. P. Grimsley, West Virginia Geol. Survey, 1910.

East of this syncline in West Virginia the beds rise abruptly in the Burning Springs anticline and then drop off to the southeast in a succession of anticlines and synclines. The Burning Springs anticline extends into Ohio, broadening out considerably in its northern development. Its axis parallels that of the Parkersburg syncline.[1] The depth of the syncline in Ohio is, on the average, 150–200 feet, and the influence of the Burning Springs anticline can be seen in the fact that 25 miles east of the southwest corner of Noble County the surface beds are only 100 feet lower than in the deepest part of the trough. Thirty miles east of the northwest corner of Noble County they lie 75 feet lower, and 30 miles east of the Muskingum-Guernsey county line they have dropped only 75 feet.

Many fields producing from all sands above the Silurian lie along this general uplift. The accumulation is a result of the general anticlinal structure, but is further controlled by sand conditions and by the local structure which in any restricted area will be found to be a series of noses, terraces, and troughs, usually lacking any general trend. It is necessary for the geologist to work out this series in detail before the sands are tested.

East of this general uplift, approaching Ohio River, the beds drop off more sharply and the local structures assume proportions more comparable with true Pennsylvania and West Virginia conditions. There is in more places a logical northeast-southwest trend, the general structure being similar to that in West Virginia east of the Burning Springs anticline.

The shallower sands produce as far west as a line between Knox and Lawrence counties. West of the Parkersburg syncline, however, the dip is sharper and there has been less folding. As a result, the shallow fields are more patchy, and their production is relatively smaller.

### SANDS

Among operators in southeastern Ohio the principal reference bench is the Pittsburgh or No. 8 coal which lies at the base of the Monongahela formation of the Pennsylvanian. It is one of the heaviest and most easily recognized of the coal beds in the state, and is sufficiently near the surface, from its outcrop to Ohio River, to serve as a guide in correlating the Pennsylvanian and Mississippian sands. Twelve producing sands occur in these two systems, the names of which, together with their average depths below the Pittsburgh coal, are as follows:

[1] The importance of these two features was first pointed out by Wilbur Stout, assistant state geologist of Ohio.

PENNSYLVANIAN AND MISSISSIPPIAN SANDS WITH DEPTHS BELOW PITTSBURGH COAL

| Sand | Depth in Feet | Sand | Depth in Feet |
|---|---|---|---|
| First Cow Run | 300 | Maxton | 950 |
| Buell Run | 350 | "Big Lime" | 975 |
| Peeker | 525 | Keener | 1,060 |
| Macksburg | 650 | Big Injun | 1,100 |
| Second Cow Run | 700 | Squaw | 1,200 |
| Salt sand | 750 | Berea | 1,600 |

The most dependable of these are the Salt sand, Keener, Big Injun, and Berea.

The Salt sand is a group of coarse-grained sandstones, in many places interbedded with shales, generally about 100 feet thick. It lies in the upper part of the Pottsville formation, and its structure follows very regularly that of the surface beds. Although it generally carries much water, in many salient structural conditions it produces gas. It rarely produces oil.

The Maxton or Lower Salt sand is the Sharon conglomerate, and marks the base of the Pennsylvanian system. It is lenticular and generally thin, and from the nature of its deposition on an eroded land surface, it is very inconsistent in structure and continuity.

"The Big lime" of the shallow fields is the Maxville limestone, which is the highest member of the Mississippian. It consists of thin-bedded limestones interbedded with sandy layers in which the production occurs. Although its thickness is in places as great as 100 feet, it is very lenticular and unreliable. Its structure is more regular than that of the Maxton sand, but its presence is dependent on Mississippian topography. Very few wells are drilled on the possibility of "lime" production alone, but many in Belmont and Monroe counties produce from this horizon.

The Keener sand occurs immediately or very close below the Maxville limestone. It is formed of alternating beds of fine- and coarse-grained sandstone, and in many places carries considerable water. The average thickness is 30 feet. It is much more uniform than either the Maxton or Maxville, and the production follows the general structure more consistently than in any other of the shallower sands.

The Injun sand is very regular in its occurrence, but very erratic in its thickness, which may range from 50 to 200 feet. It is coarse-textured and contains some beds of a conglomeratic nature. It is interbedded with thin shales. Cross-sections indicate that the variation in thickness is at the base, which is probably a result of channels cut in the soft Mississippian shales by the coarse sand. The top follows the general structure more regularly than would be expected for a sand of such variable thick-

ness, but it carries much water and is productive in few places except on the most prominent structural elevations. It may be full of water on lower anticlines where the Keener is productive. As the two sands are separated by only a few feet of shale, many good Keener wells have been ruined by drilling into Injun water, although in the higher parts of some structures, where the Keener produces gas, the Injun may produce oil.

The Squaw sand, which may be encountered from 20 to 40 feet below the Injun, is very erratic. It occurs as long narrow lenses which generally have a northeast-southwest trend and are evidently Mississippian sand bars. These beds have little relation to the general structure and are generally water-bearing. The Squaw sand has produced some high-grade oil, particularly in Columbiana County, but the accumulation is limited by the lenticular nature of the sand. Although detailed subsurface mapping has been of value after a field has been partially drilled, there is little hope of discovering new fields in this sand on geological advice.

The Berea is the most important shallow sand in Ohio, and produces in scattered fields from Medina County south and east into Kentucky, West Virginia, and Pennsylvania. Its thickness ranges from 10 to 100 feet, the average in the producing areas being about 35 feet. As a rule it is fine-grained and light colored and contains erratic lenses of coarser sand in which the heavier oil and gas "pays" are encountered. In places it is interbedded with shales, and it may be represented only by sandy shale. In other places, particularly in Columbiana, Carroll, Jefferson, Gallia, and Meigs counties, it occurs as two distinct beds separated by 1–30 feet of shale. In the western fields, which are farther from the source of the sediments, few coarser-grained beds are encountered, and the natural production of the wells is seldom encouraging. After they are shot, however, both oil and gas wells in this territory are exceptionally long-lived.

The Berea lies at the base of the Waverly formation of the Mississippian, which is somewhat variable in thickness. Its structure follows in a general way that of the surface beds, but differs locally as much as 75 feet. In northern Jefferson and Columbiana counties, due to a thinning of the Waverly, the Berea lies almost 400 feet higher in its relation to the surface beds than in Tuscarawas County.

In most places this sand is water-bearing. Although the production follows, in general, anticlinal and terraced structures, the accumulation is locally dependent on the porosity and continuity of the sand. Many dry holes have been drilled where structural conditions were most favorable.

In many places in the southern part of the state a thin sand called

the Welsh Stray, which may be correlative with the Wier sand of West Virginia, is encountered from 60 to 70 feet above the Berea. In appearance it is not unlike the Berea. It is generally dry, and it is quite possible that many outlying dry holes in southern Ohio which were supposedly drilled through the Berea were in reality only drilled through this "stray" sand. The real Berea sand can be identified anywhere by the presence of at least a few feet of the very black Sunbury shale which lies immediately above the sand.

Below the Berea lie the Ohio shales of the Upper Devonian which, as previously mentioned, thicken rapidly to the east. In New York, Pennsylvania, and West Virginia, the formation contains several producing sands which thin out and disappear to the west. In northeastern Ohio, gas production of commercial value is sometimes encountered in these shales. This has been called shale gas, and is thought to come from crevices in the shale. In reality it occurs in sandy streaks which are outlying patches of the heavier eastern sands. Geological work on these sands has been attempted, but correlation has never been successful. They are too lenticular, and the production ordinarily too small, to warrant geological consideration.

In western Guernsey County, on the large anticlinal structure which lies immediately east of the Parkersburg syncline, exceptionally good gas production, with some oil, has been found in a sandy horizon near the base of the Devonian. This sand has not as yet been correlated, but is thought to be a western development of the Oriskany of Pennsylvania. It lies from 115 to 165 feet below the top of the series of Devonian and Silurian limestones and dolomites which is also known as "the Big lime." In few places is it encountered west of Guernsey County, and it does not outcrop in the central part of the state.

A consistent water horizon occurs from 200 to 300 feet below the top of this group of limestones throughout practically the whole east half of the state. At this horizon several small gas fields have been developed in the so-called "Austinburg sand" in Ashtabula County. Two sandy water-bearing strata have been drilled through in the upper part of the "Big lime" both east and west of the Guernsey County field. At this time no definite correlation can be made, but it appears that the upper of these is the Guernsey County gas sand, possibly the Oriskany; and the lower is the general water-bearing horizon and also the Austinburg sand of Ashtabula County.

Even when the structural distortion resulting from the westward convergence of the Ohio shales is taken into account, it is still apparent that

this accumulation is controlled by the anticlinal structure, as a west dip of more than 100 feet in the surface beds amounts to at least 40 feet in the sand. East of this field the top of "the Big lime" drops 50 feet to the mile. Very few anticlines within practical drilling depth have sufficient reversal to warrant the plotting of more than a terrace at the producing horizon. The comparatively high water level in the well-developed Guernsey County structure makes the possibility of similar fields to the east appear doubtful.

The logical supposition is that if more fields are to be discovered in this sand they will lie along the uplift paralleling the Parkersburg syncline, where conditions are comparable with those in the Guernsey County field.

The so-called "Clinton" sandstone is by far the most important source of oil and gas in eastern Ohio. Although it has been drilled extensively from Lake Erie on the north to Jackson County on the south, and drilling and operating conditions are well understood, less definite geological information is available on this sand than on any other producing horizon in the state.

When first discovered, this sandstone was thought to be the equivalent of the Clinton limestone of the Lower Silurian, and was so named. Its exact location in the geological column is not yet determined. It appears that the name "Clinton" is a misnomer, and that this sand, together with the shales with which it is interbedded, should be considered either as a distinct formation of the Oswegan series or as a separate member of the Medina formation, which lies at the base of the Silurian system.

It was deposited from the southeast as a heavy sand which becomes lenticular and disappears before the Lower Silurian beds outcrop in western Ohio. In the southeast quarter of the state, in the area east of the Parkersburg syncline, the thickness averages about 100 feet; but the depth is too great for practical operation and the bed is of a quartzose nature, having practically no porosity.

The producing fields lie to the west, where the sand is always lenticular and unreliable. The depth in Huron County is about 1,500 feet, and the deepest producing wells have been in Stark County, at a depth of more than 5,000 feet.

It is everywhere hard and close-grained, and although in many places of a reddish color, the best production is found in light gray or white sand. It generally occurs as a series of lenses interbedded with gray or red shales, and probably represents both continental and shallow-water deposits.

In places the Clinton undoubtedly conforms to the general structure, but as the sand contains no water and the accumulation is confined to lenticular reservoirs, the general structure is of little consequence in the search for new fields.

Many subsurface maps show very abnormal structure in the Clinton sand. These maps are usually misleading, as there is no way to represent the actual condition by contours. The Clinton horizon constitutes the interval from 75 to 150 feet between the "Little lime," probably the true Clinton, and the Red Medina shales. As many as four lenses of sandstone may be encountered in this distance, or the sand may be absent. Maps showing the producing wells in a field do not indicate the extent of any particular sand body. The lenses differ greatly in extent, and generally overlap. Few are more than half a mile wide, and many only a few hundred yards. Intersecting cross-sections and peg models show that the accumulation follows logically the depositional structure, each lens in a producing area containing gas under a different pressure, or a separate accumulation of oil, and in places both. The gas occurs in the higher part of a lens, and where the sand is continuous over a sufficient area, considerable oil has collected in the lower parts of larger lenses. The lower limits of smaller lenses are generally marked by showings of oil in gas wells or by small oil wells.

The apparent impossibility of a widespread migration of oil and gas through such a horizon and the existence of extensive barren areas where sand conditions seem favorable suggest that the evolution of the oil and gas contained in the Clinton has been along lines of deformation coincident with the producing areas. If this is true, the deformation has been too slight in many places to be recognized in the surface beds, although drilling to the Clinton on well-defined structures in outlying territory has been generally unsuccessful.

When the entire producing area of the state is plotted, the decided northeast-southwest trend of the individual fields is apparent. This is more probably a result of similar depositional conditions than of folding.

Detailed subsurface work, confined to local problems, has been of considerable value in extending existing fields, but as yet very few new fields have been discovered on geological advice.

## CONCLUSION

The fields of eastern Ohio lie on the western edge of the great Appalachian district. The entire territory has been drilled to some extent, but there has been little systematic development. Their production is

relatively less than that of the Pennsylvania and West Virginia fields, but the oil produced is of the highest grades, and there is a ready market for gas. When all factors are considered, the opportunity for return on the same investment is as great as in parts of the country where heavier production might be obtained.

Geological conditions in the shallower sands, so far as they are understood, are similar to those in the eastern fields, where detailed geological work has been of great value. The Ohio sands were deposited farther from the source of the sediments, and as a result are more lenticular. Deformational structure cannot be considered as entirely the controlling influence in accumulation. In almost any locality in Ohio there has been sufficient drilling to enable the geologist to supplement the study of surface structure with comprehensive subsurface information.

There is every reason to believe that, with systematic geological work, many new fields will be discovered.

# OUTLINE OF WATER PROBLEMS IN NEW GROSNY OIL FIELD, RUSSIA[1]

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## ABSTRACT

The Grosny district contains three oil fields: the old and new Grosny and the Vosnesenskaja fields. There were 450 producing wells in 1926. Fifteen of these flowed, by hydrostatic pressure, and yielded half of the total daily production. Twenty-two Miocene sands are encountered in drilling. Eight of these are oil sands. Water conditions have been given special study because of the several oil sands and intermediate water sands in the same well. Several sizes of casing are required to shut off the waters above each producing sand. In distinguishing the several waters and thus in correlating the sands, the characteristics of the waters were calculated after the method of Chase Palmer in reacting values and chemical properties. Tables and a chart are given, showing these comparative properties. The author concludes that edge water is encroaching and the future production should be small.

## INTRODUCTION

In the last three years the underground conditions have been studied on a general scale, and, as a result of the investigations, some of the underground conditions may now be considered as solved.

In the Grosny oil fields are very interesting geological conditions. The oil-bearing strata are of Tertiary age. The lower Miocene has a thickness of nearly 2,000 feet. There are twenty-two sands interbedded with shale and some siliceous dolomites.

The Tertiary group is exposed in the Black Mountains where the sands can be saturated with fresh water.

Near Grosny there are many anticlines, but in most of them the oil-bearing formation is exposed, and only oil seepages and many hot springs occur. The temperatures of the water range from 170° to 190° F. The flows of the largest springs amount to 20,000 or 30,000 barrels daily.

In the oil fields the oil strata are covered, particularly in the new field, by not less than 1,000 feet of shales.

In the oil fields at places near sea-level many hot artesian springs issue from the wells drilled for oil.

The origin of hot water in the springs can be explained through the

[1] Summary of paper read before the Association at the Dallas meeting, March 25, 1926. Manuscript received by the editor June, 1927.

[2] Geologist, Grosny, Kabardinskaja No. 3.

heating of the water in the big syncline between the Black Mountains and the northern anticlines, and the very quick movement of the water through the porous sand to the outcrop at different places. These moving waters cause high temperatures in the oil fields.

For example, the chart of the coefficient of geothermal gradient in the new oil field shows that the average gradient is 12 feet for each degree F., against 30 or 40 feet at normal conditions.

Some of the Russian geologists thought that the origin of hot water is in connection with volcanic activity, but the springs are coming out of Miocene sands and the older formations range in age from Oligocene to Jurassic, having a thickness of more than 10,000 feet. Nowhere in the vicinity are outcrops of volcanic rocks.

The Grosny district is composed of three fields. The old and the new Grosny fields have an average daily production of about 22,000 barrels each. The little field at Vosnesenskaja produces 200 barrels daily. Altogether, there are 450 wells. Fifteen of these are flowing wells which yield 50 per cent of the total production.

In the flowing well the production is by hydrostatic pressure and not by gas, because the gas-oil ratio is very low (between 100 and 250 cubic feet per barrel). As a rule gas content and casing-head pressure are constant.

Water problems in the New Grosny oil field have been carefully studied. In this field twenty-two sands and interbedded shales have a thickness of about 1,750 feet. Eight of these sands are known as oil sands; some others are water sands; and some are not determined.

Because top and many intermediate waters are present, the water shut-off in the wells must be effected above each oil sand. This necessitates very large diameters of casing, because one well generally produces oil from two or three different sands.

The producing wells do not have a long life, because of depletion and increasing water production.

The production of oil with high percentage of water and the encountering of many intermediate water sands are the principal reasons for a careful study of the water problems.

## CHEMICAL CHARACTERISTICS OF WATER

In the New Grosny oil fields most of the waters which accompany the oil are sulphate waters, but the top waters are reduced. Waters without sulphate are commonly encountered in oil fields, but the surface, top, and edge waters are sulphate waters.

The presence of sulphate waters in the New Grosny field is explained by the fact that oil is found only in the sands on the top of the structure; down the flanks of the structure the sands are occupied by edge water, which is moving from the outcrop in the Black Mountains to the different springs in the lower part of the country. The waters in the fields are of two different kinds: top waters and oil waters. The top waters are salty, with solids amounting almost to 60 grams per liter. These waters must be considered as altered sea waters. They are in formations consisting chiefly of shales, a few calcareous shales, but practically no sands.

In the oil horizon are encountered weak mineralized waters with solids ranging from 0.80 to 5 grams per liter. Geologically, the top waters and the oil waters are found in formations which are well characterized by different fossils.

In the last three years some detailed water analyses and many field analyses have been made. In the latter, solids were determined by electrical resistance and CL, $SO_4$, and $CO_3$ anions per liter. By comparing only the amounts of acids in the different waters their origin could be determined in most cases, but some wells contain different water in which the amounts of $SO_4$ and $CO_3$ are changeable.

Until 1923 the explanation for this could not be given, because the waters were compared only by the amounts of different anions. In 1921 and 1922 the waters in Grosny were calculated after the method of Chase Palmer in reacting values and chemical properties.

In trying to compare the waters by this method it was found that some waters from distinctly different sands have the same properties (Table I).

When we compare the properties of samples No. 5 and No. 8, we can see that the properties and some ratios are the same, but the waters are from different sources.

On the other hand, when we compare the water samples No. 6 and No. 8, we cannot say positively that the waters are from the same sand. Furthermore, when we compare not only the properties which are expressed in percentage, but also consider the sum of solids, or what is the same, but expressed more chemically, the sum of reacting values of acids or alkalis, we see that samples No. 5 and No. 8 contain different amounts of acids, or different concentration.

Analyses No. 7 and No. 8 have the same amount of acids and alkalis. When we take into consideration also this characteristic, then we must say that No. 5 and No. 8 are different waters, and waters No. 7 and No. 8 are from the same sand. The last three analyses have some different proper-

ties, and we must suppose that for some reason the waters are changed. Such a change was first discovered in some wells in the middle of 1923,

### TABLE I

INTERPRETATION OF WATER ANALYSES IN NEW GROSNY OIL FIELD

| Samples | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Wells | 1/20 | 6/21 | 5/69 | 1/74 | 22/36 | 2/42 | 2/60 | 4/35 |
| Sands | Top Waters | I Sand | | III Sand | | XI Sand | XIII Sand | |
| Properties of reaction in per cent | | | | | | | | |
| Primary Salinity | 95.8 | 76.2 | 70.6 | 43.2 | 58.4 | 32.2 | 62.2 | 57.8 |
| Secondary Salinity | 1.2 | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| Primary Alkalinity | ........ | 20.6 | 22.2 | 55.8 | 37.8 | 63.0 | 22.8 | 33.6 |
| Secondary Alkalinity | 3.0 | 3.2 | 7.2 | 1.0 | 3.8 | 4.8 | 12.5 | 8.6 |
| Per cent of r $SO_4$ in r $SO_4$ − r Cl | ........ | 7.9 | 40.0 | 44.5 | 57.9 | 64.7 | 71.1 | 61.6 |
| Ratio r $CO_3$ : r $SO_4$ | ........ | 4.0 | 1.0 | 3.0 | 1.2 | 3.3 | 0.86 | 1.2 |
| Constituents (Mgr. per liter) | | | | | | | | |
| Cations | | | | | | | | |
| Na | 14.3587 | 2.1576 | 1.2765 | 0.8841 | 1.0146 | 0.6546 | 0.3077 | 0.3233 |
| Ca | 0.3466 | 0.0334 | 0.0157 | 0.0081 | 0.0197 | 0.0265 | 0.0400 | 0.0267 |
| Mg | 0.1394 | 0.0169 | 0.0424 | ........ | 0.0095 | 0.0013 | 0.0046 | ........ |
| $Fe_2O_3.H_2O_3$ | 0.0132 | 0.0176 | 0.0200 | 0.0060 | 0.0076 | 0.0066 | 0.0100 | 0.0176 |
| Anions | | | | | | | | |
| $SO_4$ | ........ | 0.2831 | 0.8283 | 0.3713 | 0.7441 | 0.2761 | 0.3380 | 0.2634 |
| Cl | 22.4400 | 2.4100 | 0.9170 | 0.3433 | 0.3999 | 0.1127 | 0.1010 | 0.1212 |
| $CO_3$ | 0.6057 | 0.6897 | 0.5370 | 0.6840 | 0.5730 | 0.5625 | 0.1800 | 0.1949 |
| $SiO_2$ | ........ | ........ | 0.0524 | 0.0340 | ........ | 0.0586 | 0.0635 | ........ |
| Solids—grams per liter | 36.8400 | 8.2200 | 3.6580 | 2.2280 | 2.6100 | 1.8112 | 1.0190 | 0.8700 |
| **REACTING VALUES (EQUIVALENT, MGR. H)** | | | | | | | | |
| Alkalis and alkali earths | | | | | | | | |
| Na | 623.17 | 93.64 | 55.40 | 38.32 | 44.03 | 28.41 | 13.35 | 14.03 |
| Ca | 12.29 | 1.67 | 0.78 | 0.40 | 0.98 | 1.32 | 2.0 | 1.32 |
| Mg | 11.44 | 1.39 | 3.48 | ........ | 0.78 | 0.11 | 0.38 | ........ |
| Total | 651.90 | 96.70 | 59.66 | 38.77 | 45.79 | 29.84 | 15.73 | 18.35 |
| Strong and weak acids | | | | | | | | |
| $SO_4$ | ........ | 5.89 | 12.23 | 7.72 | 15.48 | 5.24 | 7.03 | 5.48 |
| Cl | 632.81 | 67.96 | 25.86 | 9.68 | 11.28 | 3.18 | 2.85 | 3.42 |
| $CO_3$ | 20.12 | 22.97 | 12.88 | 22.78 | 19.09 | 18.73 | 5.99 | 6.49 |
| Total | 652.99 | 96.82 | 60.97 | 40.18 | 45.84 | 27.65 | 15.87 | 15.39 |
| **REACTING VALUES IN PER CENT** | | | | | | | | |
| Alkalis and alkali earths | | | | | | | | |
| Na | 47.9 | 48.4 | 46.4 | 49.5 | 48.1 | 47.6 | 42.5 | 45.7 |
| Ca | 1.3 | 0.9 | 0.7 | 0.5 | 1.1 | 2.2 | 6.4 | 4.3 |
| Mg | 0.8 | 0.7 | 2.9 | ........ | 0.8 | 0.2 | 0.1 | ........ |
| Total | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| Strong and weak acids | | | | | | | | |
| $SO_4$ | ........ | 3.0 | 14.1 | 9.6 | 16.9 | 10.4 | 22.1 | 17.8 |
| Cl | 48.50 | 35.1 | 21.2 | 12.0 | 12.3 | 5.2 | 9.0 | 11.1 |
| $CO_3$ | 1.8 | 11.9 | 14.7 | 28.4 | 20.8 | 33.9 | 18.9 | 21.1 |
| Total | 50.00 | 50.0 | 50.00 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |

but could not be defined exactly until the time of investigation of the water conditions in well No. 10/42 (Table II).

In this table are shown only the acids, and this is sufficient for practical use. The anions of acids are calculated in reacting values and summarized. As a special property the ratio between CL and $SO_4$ plus $CO_3$ was taken, or a ratio between one strong acid and a sum of strong and weak acids. Such a property, as will be shown farther on, must be taken

TABLE II

Analyses of Water from the Well 10/42 (Depth, 2,615 Feet)

| No. | Sample Taken | Solids (Grams per Liter) | Anions | | | Reacting Value | | | | Cl |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $SO_4$ | Cl | $CO_3$ | $SO_4$ | Cl | $CO_3$ | Total | $\frac{SO_4}{+CO_3}$ |
| Analyses of Water Associated with Oil | | | | | | | | | | |
| 1.... | 4 V 21 | ...... | 0.4056 | 0.1388 | ...... | 8.44 | 3.91 | ...... | ...... | ...... |
| 2.... | 6 V 21 | 1.136 | 0.4106 | 0.1424 | 0.1431 | 8.54 | 4.02 | 4.77 | 17.33 | 0.30 |
| 3.... | 22 III 22 | 1.044 | 0.3954 | 0.1177 | 0.2220 | 8.22 | 3.30 | 7.39 | 18.91 | 0.21 |
| 4.... | 30 I 24 | 0.990 | 0.4002 | 0.1300 | 0.1380 | 8.32 | 3.67 | 4.66 | 15.65 | 0.28 |
| 5.... | 11 V 24 | 1.000 | 0.4938 | 0.1400 | 0.1530 | 10.27 | 3.95 | 5.09 | 19.31 | 0.26 |
| 6.... | 14 X 24 | 0.960 | 0.3227 | 0.1264 | 0.1560 | 6.71 | 3.56 | 5.19 | 15.36 | 0.30 |
| The Well Was Shut in for 3½ Months | | | | | | | | | | |
| 7.... | 16 III 25 | 0.900 | 0 | 0.1500 | 0.3820 | 0 | 4.23 | 12.59 | 16.82 | 0.34 |
| 8.... | 17 III 25 | 0.850 | 0 | 0.1320 | 0.3630 | 0 | 3.72 | 12.09 | 15.81 | 0.31 |
| 9.... | 18 III 25 | 0.880 | 0 | 0.1500 | 0.3660 | 0 | 4.24 | 12.19 | 16.42 | 0.35 |
| After 20 Hours' Pumping | | | | | | | | | | |
| 10.... | 28 III | 0.950 | 0.0534 | 0.1540 | 0.3150 | 1.21 | 4.34 | 10.49 | 16.04 | 0.32 |
| 11.... | 29 III | 0.940 | 0.0930 | 0.1430 | 0.3210 | 1.93 | 4.03 | 10.69 | 16.65 | 0.32 |
| 12.... | 29 III | 0.980 | 0.1920 | 0.1386 | 0.2280 | 3.99 | 3.91 | 7.59 | 15.49 | 0.34 |
| After 2 Days' Pumping | | | | | | | | | | |
| 13.... | 1 IV | 1.010 | 0.4098 | 0.1320 | 0.1590 | 8.52 | 3.72 | 5.29 | 17.53 | 0.27 |
| 14.... | 2 IV | 0.920 | 0.3424 | 0.1520 | 0.1800 | 7.23 | 4.29 | 5.99 | 17.51 | 0.32 |
| 15.... | 2 IV | 0.960 | 0.4098 | 0.1140 | 0.1350 | 8.52 | 3.21 | 4.50 | 16.23 | 0.25 |

into consideration to identify the water in the same sand without eliminating some changes which can be encountered in the same water.

The first six analyses have the same properties. These were taken from the well when it originally produced about 8,000 barrels of oil daily, and most recently when it produced about 20 barrels daily. During a period of four years the water practically had the same properties. In

October, 1924, the well was shut down because of small production, and after some time it was decided to deepen the well.

Before commencing, however, the geological department of Grosneft wished to be sure that the water conditions had not changed. To be sure of this, after $3\frac{1}{2}$ months water samples were taken. Samples Nos. 7, 8, and 9 show the properties of this water. All $SO_4$ is gone, and in reacting value the amount of $CO_3$ is increased to the sum of $SO_4$ and $CO_3$. This can be easily seen from the amount of reacting value of acids. When we compared the total amount of acids in the first six samples and in Nos. 7, 8, and 9, we find no difference; and there is also no difference between the ratio of CL to $SO_4$ plus $CO_3$. In other words, in the last three samples $SO_4$ is reduced to $CO_3$.

To prove that during the shut-down period of the well such a substitution or reduction was possible, the well was pumped for some time. In the beginning there appeared water with some $SO_4$, but after pumping two days the well contained water with the original properties.

Not only in this well, but in some others also, it could be observed that the waters from different sands are sometimes sulphate, sometimes reduced, but always the amount of reacting value of acids and the ratio are practically the same.

These data give very good characteristics of waters and serve as a means of distinguishing the waters from different sands.

In the last 3 or 4 years about 1,000 water analyses were made in the new oil fields and most of them indicate their origin. In Table III are 24 analyses from six different horizons, taken from a paper published in Russia.[1] In each horizon, practically, there are two kinds of water: sulphate and reduced waters. The waters in different sands can well be distinguished one from another when using as comparable properties the amounts of reacting value of acids, and the special ratio.

For better distinguishing the different waters, a chart (Fig. 1) was made on logarithmic paper, in which the ordinates show the reacting value of acids, and the abscissae indicate the ratio. In this chart are shown nearly 150 analyses, and they are grouped in some manner together. All the water analyses which have nearly the same properties are circled, and all the waters in each circle are considered as waters from one sand. Reduced and sulphate waters can be distinguished in nearly every sand on the chart, but the properties of both types of water are the same.

[1] Lindtrop, "Water in New Grosny Fields," *Neftganoe and Slautcevoe Nosjarstwo*, No. 6 (1925), pp. 903–31.

## TABLE III

### Water Analyses

| Well | Depth of Well (Feet) | Solids (Grams per Liter) | Anions $SO_4$ | Anions Cl | Anions $CO_3$ | Reacting Value $SO_4$ | Reacting Value Cl | Reacting Value $CO_3$ | Total Equiv. H Mgr. | Ratio $\frac{Cl}{SO_4 + CO_3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Top Water—Sulphate** | | | | | | | | | | |
| 32/4..... | 1142 | 39.180 | 0.277 | 27.162 | 0.534 | 16.16 | 265.92 | 16.28 | 798.91 | 23.25 |
| **Top Water—Reduced** | | | | | | | | | | |
| 20/1..... | 1183 | 34.670 | ...... | 21.869 | 0.468 | ...... | 616.21 | 15.58 | 632.29 | 39.56 |
| 34/5..... | 1420 | 44.500 | ...... | 25.528 | 0.432 | ...... | 721.30 | 14.39 | 735.69 | 50.17 |
| 30/1..... | 1820 | 39.650 | ...... | 28.483 | 0.681 | ...... | 803.22 | 22.60 | 825.90 | 35.45 |
| **I Sand (Edge Water)** | | | | | | | | | | |
| 18/4..... | 1650 | 3.80 | 0.6690 | 1.3200 | 0.6720 | 13.92 | 37.22 | 22.38 | 73.52 | 1.03 |
| 24/1..... | 1469 | 3.85 | 0.7264 | 1.0154 | 0.5700 | 15.11 | 28.63 | 18.98 | 62.72 | 0.84 |
| **I Sand (Water in Oil Wells)** | | | | | | | | | | |
| 33/4..... | 1499 | 7.970 | 0.1433 | 3.905 | 0.7380 | 2.98 | 110.12 | 24.58 | 157.68 | 4.00 |
| 75/2..... | 1458 | 8.680 | 0.4578 | 3.9764 | 0.5820 | 9.52 | 112.13 | 13.38 | 141.03 | 3.88 |
| **I Sand (Reduced Water in Oil Wells)** | | | | | | | | | | |
| 18/22.... | 1246 | 5.22 | ...... | 2.100 | 1.3680 | ...... | 59.22 | 45.55 | 104.22 | 1.30 |
| 34/1..... | 1407 | ...... | ...... | 3.3775 | 0.7290 | ...... | 95.25 | 24.28 | 119.53 | 3.93 |
| **III Sand (Sulphate Waters)** | | | | | | | | | | |
| 20/9..... | 1449 | 1.790 | 0.8658 | 0.1538 | 0.3540 | 18.01 | 4.37 | 11.77 | 34.14 | 0.15 |
| 33/1..... | 1428 | 2.087 | 0.1860 | 0.1800 | 0.8715 | 3.87 | 5.08 | 29.02 | 37.97 | 0.15 |
| **III Sand (Reduced Waters)** | | | | | | | | | | |
| 24/5..... | 1201 | 2.000 | ...... | 0.2360 | 0.9270 | ...... | 6.66 | 30.87 | 37.53 | 0.22 |
| 73/1..... | 1344 | 2.000 | ...... | 0.2200 | 0.9990 | ...... | 6.20 | 30.27 | 36.47 | 0.20 |
| **X Water Sand** | | | | | | | | | | |
| 18/3..... | 1876 | 0.860 | 0.1646 | 0.0386 | 0.4230 | 3.42 | 1.09 | 14.09 | 18.60 | 0.062 |
| 50/2..... | 2205 | 0.890 | 0.1729 | 0.0462 | 0.2760 | 3.60 | 6.30 | 3.19 | 14.09 | 0.102 |
| **X Sand (Reduced Water)** | | | | | | | | | | |
| 18/3..... | 1876 | 0.920 | ...... | 0.0384 | 0.4380 | ...... | 1.08 | 14.59 | 15.67 | 0.024 |

TABLE III—*Continued*

| Well | Depth of Well (Feet) | Solids (Grams per Liter) | Anions | | | Reacting Value | | | Total Equiv. H Mgr. | Cl |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $SO_4$ | Cl | $CO_3$ | $SO_4$ | Cl | $CO_3$ | | $SO_4+CO_3$ |
| **XI Sand (Water in Oil Wells)** | | | | | | | | | | |
| 54/12.... | 2314 | 1.500 | 0.4002 | 0.1000 | 0.4560 | 8.32 | 2.82 | 15.18 | 26.32 | 0.120 |
| 24/2..... | 1932 | 1.540 | 0.2850 | 0.1080 | 0.7500 | 5.93 | 3.05 | 24.92 | 33.85 | 0.090 |
| **XIII Sand (Water in Oil Wells, Edge water)** | | | | | | | | | | |
| 35/4..... | 2499 | 1.096 | 0.3954 | 0.1190 | 0.1710 | 8.22 | 3.36 | 5.69 | 12.27 | 0.24 |
| 60/3..... | 2501 | 1.141 | 0.3471 | 0.1520 | 0.1578 | 7.16 | 4.29 | 5.25 | 16.70 | 0.35 |
| **XIII Sand (Reduced Water Partly)** | | | | | | | | | | |
| 33/1..... | 2093 | 0.760 | 0.1506 | 0.1180 | 0.2280 | 3.13 | 3.33 | 7.59 | 14.05 | 0.31 |
| 35/4..... | 2499 | 0.930 | 0.0921 | 0.1676 | 0.2910 | 2.02 | 4.23 | 9.69 | 16.44 | 0.40 |
| 42/10.... | 3615 | 0.880 | ...... | 0.1500 | 0.3660 | ...... | 4.33 | 12.19 | 16.42 | 0.40 |

There are also some mixed waters which are commonly placed between the circles, but they are rare. Most of the waters are encountered together with oil, and contain sulphate. From this the conclusion is drawn that the water is edge water, which is coming up the dip and is produced in the wells. In other words, it means that the sands are depleted and exhausted and the future production should be small.

Before arriving at such a conclusion, it was assumed that in most of the wells top or bottom water is present because of bad mechanical conditions or poor water shut-off. From a scientific standpoint, the analysis of water shows that the time for reduction of water may be very short and may be going on only through weeks or months, and not during an infinitely long time, as was formerly believed.

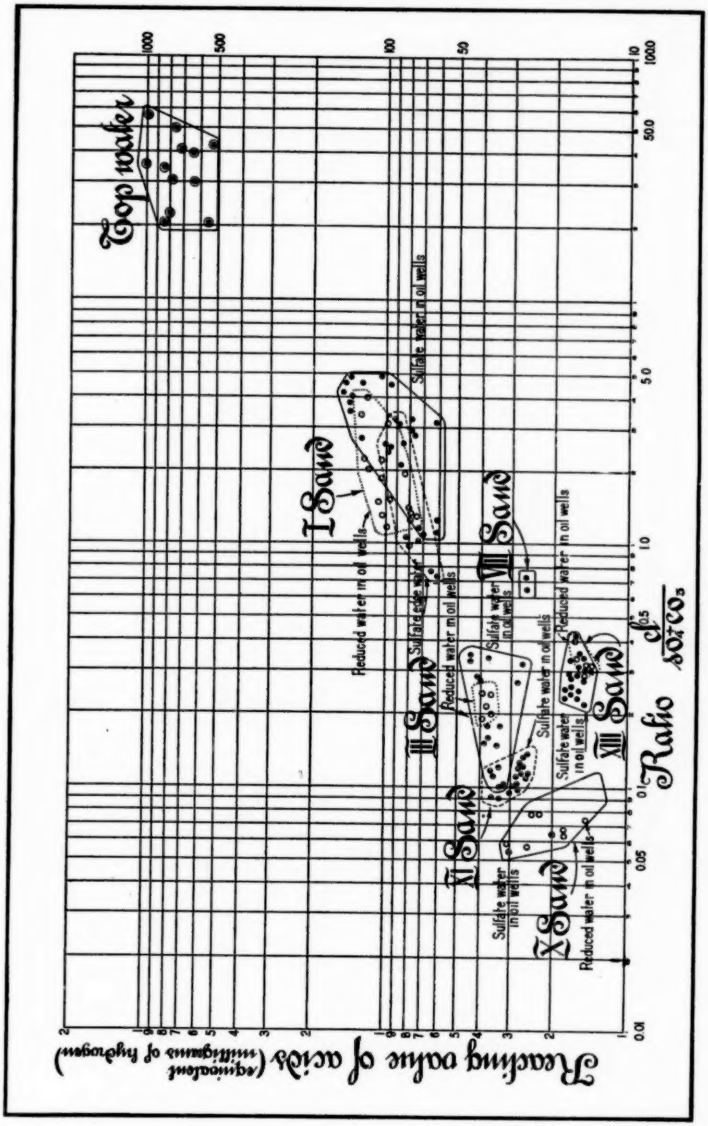
Top water
I Sand
III Sand
VIII Sand
XI Sand
X Sand
XIII Sand
Sulfate water in oil wells
Reduced water in oil wells
Sulfate edge water
Reacting value of acids (equivalent milligrams of hydrogen)
Ratio $\frac{Cl}{SO_4+CO_3}$

FIG. 1

# BURBANK FIELD, OSAGE COUNTY, OKLAHOMA[1]

J. MELVILLE SANDS[2]
Bartlesville, Oklahoma

## ABSTRACT

Local structural conditions seem to have had little influence on the concentration of oil in this field. The area is an undulating monocline with a general dip to the west of about 35 feet to the mile. On the north and east sides of the field the oil-bearing sand grades in a short distance into an impervious shale, and this impervious shale prevents the oil from traveling farther up the dip. On the west and lower side of the field the oil is in contact with salt water. The oil production from each well also seems to be in proportion to the porosity of the sand in the immediate vicinity of the well, and has little if any relation to rock deformation. The shale barrier north and east of the field, therefore, has been the medium which retained the oil in its present position, and the porosity of the reservoir rock in the vicinity of each well has regulated that well's daily and ultimate production.

## INTRODUCTION

The purpose of this paper is to discuss the following phenomena of this field: (1) The influence of structure on petroleum accumulation and concentration. (2) The relation between the porosity of the reservoir rock, and its oil content and production.

## HISTORY

The first oil produced in Osage County was on its eastern line near Bartlesville, Oklahoma, and from the Bartlesville sand. This was found at a depth of 1,600 feet, and is near the base of the Pennsylvanian series. It is the most widespread and prolific of any oil sand in the county. The western limit of this sand, as now known, is a line running northeast and southwest nearly through the center of the county. Because developments started in the eastern part of the county and worked west, operators, after drilling many dry holes west of the center of the county, became reluctant to drill even on well-known structures in the western Osage, in which the Burbank field is located. It was not until the Marland Oil Company drilled in its first well in the Burbank field in May, 1920, in the SE. $\frac{1}{4}$ of Sec. 36, T. 27 N., R. 5 E., and the Carter Oil Company drilled in its first well in September, 1920, in Sec. 9, T. 26 N., R. 6 E., on

[1] Presented by title before the Association at the Tulsa meeting, March 26, 1927. Manuscript received by the editor May 13, 1927.

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two small anticlines, that the possibilities of the Burbank field were recognized by oil men in general. Since that time, thirteen sales of oil leases have been held by the Osage agency under the direction of the United States Government. At these sales, quarter-sections are auctioned to the highest bidder. So far the highest price paid has been $1,990,000 for the 160 acres in the NE. ¼ of Section 14, T. 27 N., R. 5 E., which was bought by the Midland Oil Company. Including the small part of the field which is in Kay County, 170 quarter-sections are producing. More than 130,000,000 barrels of oil have been extracted from the field. The production at present is 43,000 barrels daily from 2,000 wells. With one well to ten acres, the recovery to date averages 6,500 barrels per acre, while some leases have produced 20,000 barrels per acre. Figure 4 shows the production-decline curve of this field, the average production per well per day, and the average number of wells producing, from 1921 to date.

## STRATIGRAPHY

The stratigraphy of Osage County has been so thoroughly worked by all of the oil companies operating in that district, and also has been described so completely in several publications,[1] particularly those of the United States Geological Survey[2] and the Oklahoma Geological Survey,[3] that space will not be taken here to describe the different members in detail. The surface rocks of the entire county, with the exception of a small area in the northwest part, are of Pennsylvanian age; Permian rocks overlie the Pennsylvanian conformably in that area. The contact of the Permian and Pennsylvanian extends northeast and southwest, through the eastern side of the Burbank field, so that most of the limestones used in working the surface structure are of Permian age. The total thickness of the Pennsylvanian series in Osage County is about 2,900 feet. It contains several different producing horizons in different parts of the county, some fields producing from several horizons at the same time. The Burbank field, however, is only producing commercially from the Burbank sand, which is near the base of the Pennsylvanian series at a depth of 2,800 feet in the southeastern part of the field, and a depth of 3,200 feet in the northwestern portion. It is a fine-grained, siliceous sand, having a calcareous cementing material. Its thickness ranges from 50 to 80 feet. Melcher's examination[4] shows the pore space to range from 13.7 per cent

[1] J. M. Sands, "Burbank Field, Osage County, Oklahoma," *Bulletin Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 5 (1924), pp. 584–92.

[2] *U.S.Geol. Surv. Bulletin 686.* [3] *Oklahoma Geol. Surv. Bulletin 19.*

[4] "Texture of Oil Sands with Relation to the Production of Oil," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 (1924), pp. 716–74.

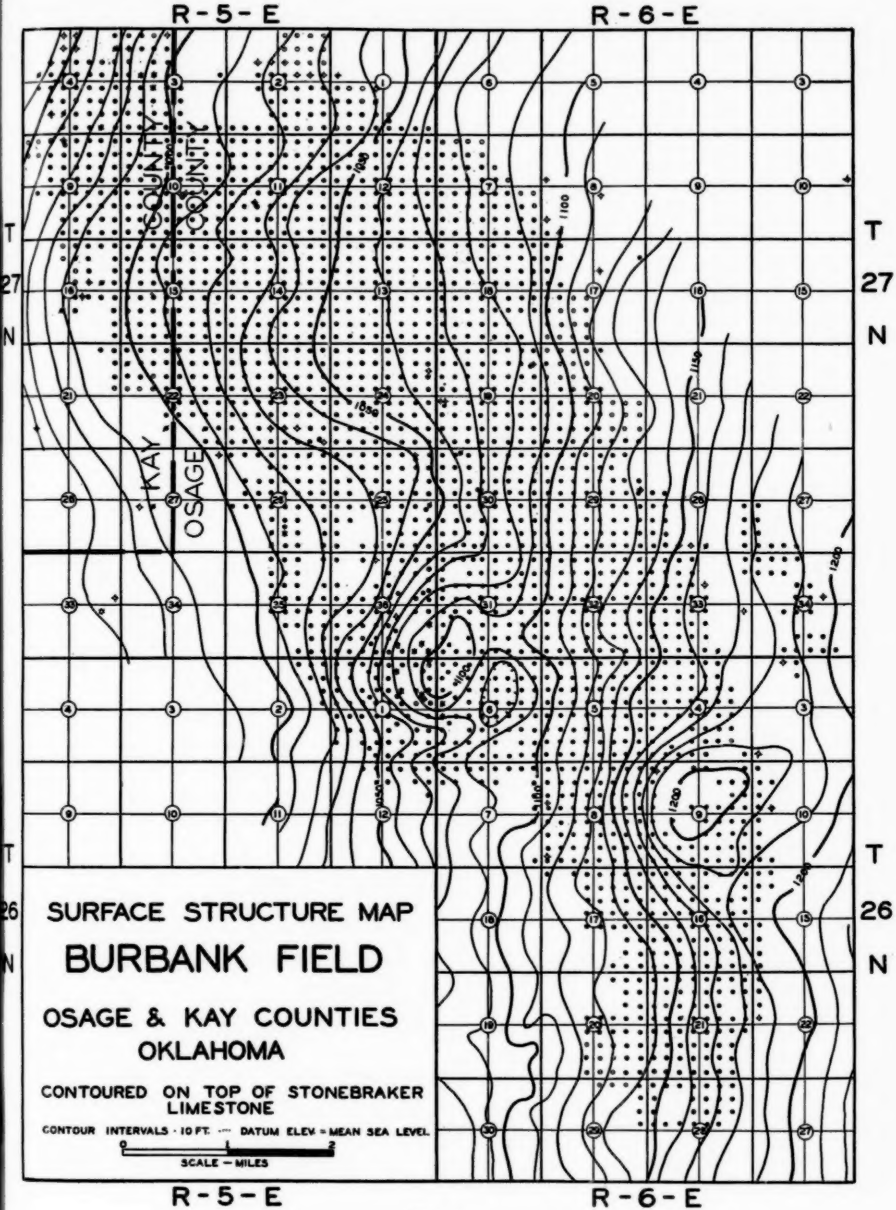
R-5-E
R-6-E
T
27
N
T
26
N
KAY COUNTY
OSAGE COUNTY
SURFACE STRUCTURE MAP
BURBANK FIELD
OSAGE & KAY COUNTIES
OKLAHOMA
CONTOURED ON TOP OF STONEBRAKER LIMESTONE
CONTOUR INTERVALS - 10 FT. — DATUM ELEV. = MEAN SEA LEVEL
SCALE — MILES
R-5-E
R-6-E

FIG. 1

to 32.7 per cent by volume. The thickness of the sand is not uniform, and in some places there is a stratum of blue shale ranging from a few inches to 3 feet in thickness at about 50 feet from the base of the sand. Where the sand is thickest, about 80 feet, the sand above this blue shale is about 30 feet thick and carries nothing but gas. It is quite probable that the range in the thickness of the Burbank sand is caused altogether by the range in thickness of this upper member, and that, where the oil is found at the surface of the sand, this upper member is very thin, or in some places entirely absent. Though the lower 50 feet of the sand is generally a pure sand without any shale breaks, its porosity and content of calcareous material differ, so that the sand is probably not productive throughout its total thickness. The production comes from three or four different zones encountered at different depths, and it is quite probable that not more than two-thirds of the total thickness is productive.

Stratigraphically, the Bartlesville and the Burbank sands in Osage County, Oklahoma, and the Rainbow Bend and Fox Bush sands in Kansas, seem to be at about the same horizon. The Bartlesville sand, however, is a blanket formation covering a large part of northeastern Oklahoma and a small part of southeastern Kansas, while the other three sands mentioned have much smaller areas and may be in the form of large lenses. In the vicinity of the Burbank field, the Burbank sand has been encountered as a water sand considerably outside the field in several localities, and within the last year the Kewanee pool, 1 mile east of Burbank production, and the Fairfax pool, located 6 miles south of the Burbank pool, have developed production in this sand. Whether or not these two pools ultimately will be found to connect with the Burbank field and also whether or not the sand of the Fairfax pool will be found to continue south to connect with the Bartlesville sand, will remain for further development to discover. There is a distance, however, of 18 miles between the western edge of the Bartlesville sand near Pawhuska and the eastern edge of the Burbank sand in that field proper.

The Burbank sand is separated from the "Mississippi lime" below by 40–70 feet of blue Cherokee shales. The "Mississippi lime" here is a series of hard, semicrystalline, blue limestone beds, divided by more shaly or chalky, softer members. The total thickness is 320 feet. Beneath this is 130 feet of black Chattanooga shales, beneath which is the "Wilcox" sand. In this field, this sand is rather fine grained and calcareous, but is sufficiently porous to have a showing of oil and a hole full of water. This oil was encountered in the Carter well in Sec. 9, T. 26 N., R. 6 E., which is located in the highest part of the field. This well should have been a

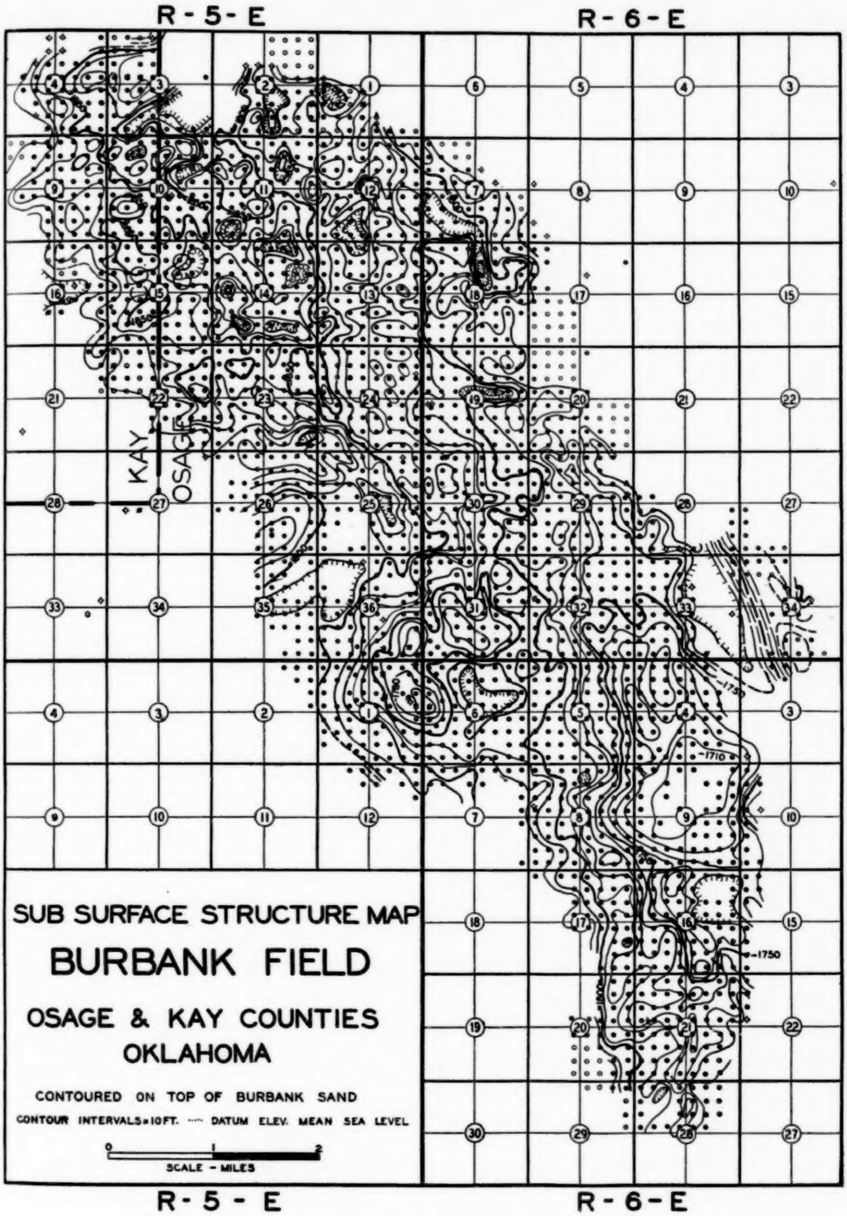
R-5-E
R-6-E
KAY
OSAGE
SUB SURFACE STRUCTURE MAP
BURBANK FIELD
OSAGE & KAY COUNTIES
OKLAHOMA
CONTOURED ON TOP OF BURBANK SAND
CONTOUR INTERVALS = 10 FT. DATUM ELEV. MEAN SEA LEVEL
SCALE - MILES
R-5-E
R-6-E

FIG. 2

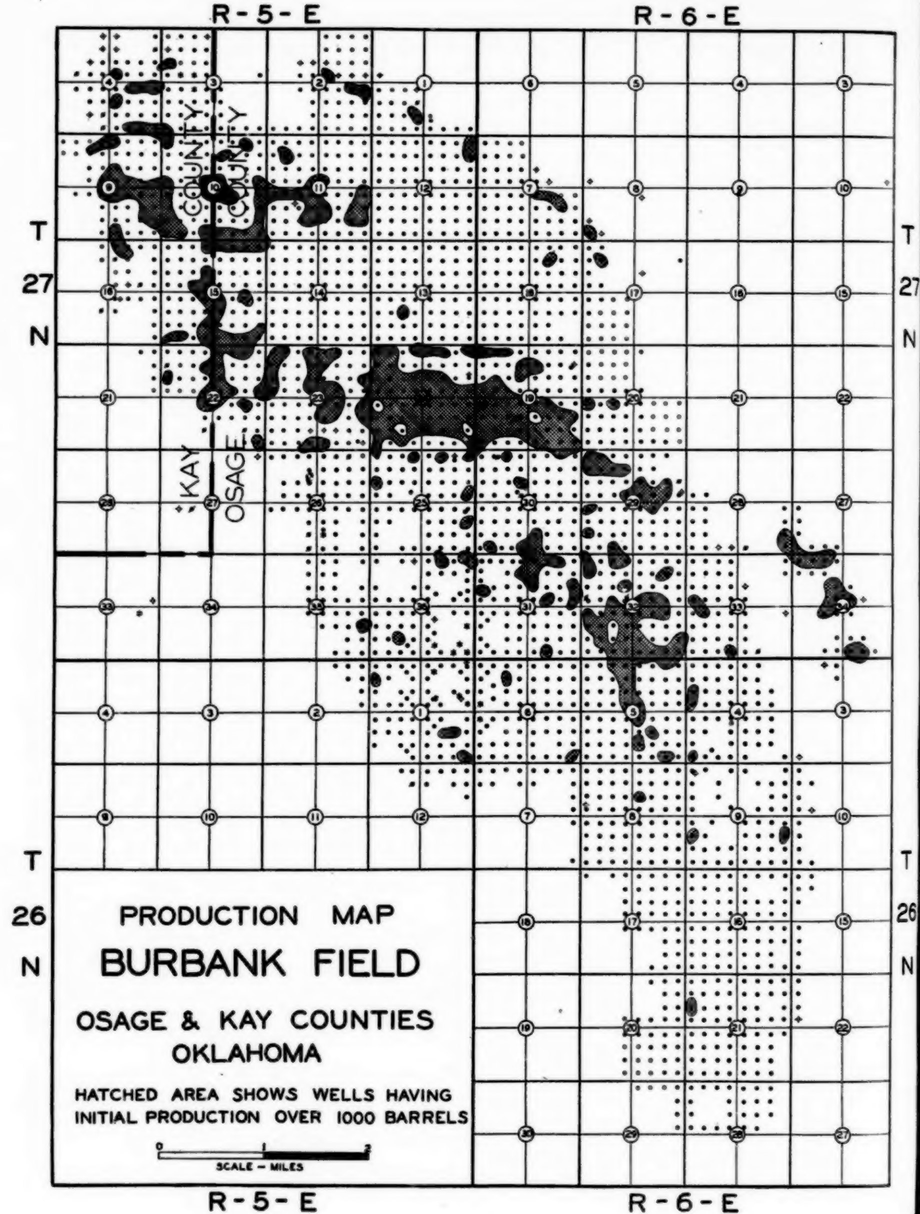
R-5-E
R-6-E
T
27
N
T
26
N
KAY
OSAGE
COUNTY
COUNTY
PRODUCTION MAP
BURBANK FIELD
OSAGE & KAY COUNTIES
OKLAHOMA
HATCHED AREA SHOWS WELLS HAVING
INITIAL PRODUCTION OVER 1000 BARRELS
SCALE – MILES

Fig. 3

splendid test for production in this sand. It is therefore improbable that any "Wilcox" production will be found in this field, although, because of the existence of this sand in this district and the showing of oil in it, there is very good reason to suppose that in districts in this vicinity where conditions have been more favorable for oil depositions in this sand, there should be production developed in it. Beneath the "Wilcox" sand is 860 feet of siliceous lime. This lime is composed of thick, cherty members of hard gray siliceous limestone interbedded with thinner members of a more shaly or sandy nature. No oil or gas was encountered in it. Below the siliceous limestone is granite. This granite is much the same class as that found in the granite ridge extending through Kansas and the northwest corner of Osage County. The granite was encountered in only one well in the field, that being the well of the Carter Oil Company located in the northwest corner of the NW. $\frac{1}{4}$ of Sec. 9, T. 26 N., R. 6 E. The granite was encountered at 4,240 feet. A type well log of the field is shown in Figure 5. The lower 700 feet is taken from the Carter Oil Company's well.

## STRUCTURAL CONDITIONS

The Burbank field is included in the territory situated on the western flank of the great regional uplift which has for a center the Ozark Plateau. This west flank includes northwestern Arkansas, northeastern Oklahoma, southeastern Kansas, and southwestern Missouri. The strata in Osage County dip a little north of west at the rate of about 30 feet to the mile, this dip being changed and reversed in different localities, according to local structure conditions.

Figure 1 shows surface structural conditions in the Burbank field, using the Stonebreaker limestone as datum. The general dip is about 35 feet to the mile, approximately due west. The only reversals developed are a small dome with about 20 feet of closure in Sec. 9, T. 26 N., R. 6 E. and a still smaller dome with 10 feet of closure at the intersection of T. 26–27 N. and R. 5–6 E., the latter being 100 feet lower than the former.

Figure 2 shows structural conditions developed on top of the Burbank sand. A comparison of these two figures shows a much greater deformation of the subsurface structure than of the surface. There are several small domes and synclines, and the two small domes shown on the surface have had their closure greatly increased. The one in Sec. 9, T. 26 N., R. 6 E. shows 50 feet of closure, while in the one at the intersection of T. 26–27 N., and R. 5–6 E. there are 35 feet of closure.

The structural conditions of the Burbank field may then be called an undulating monocline dipping at the rate of about 35 feet to the mile in a westerly direction, with the largest deformation being the previously

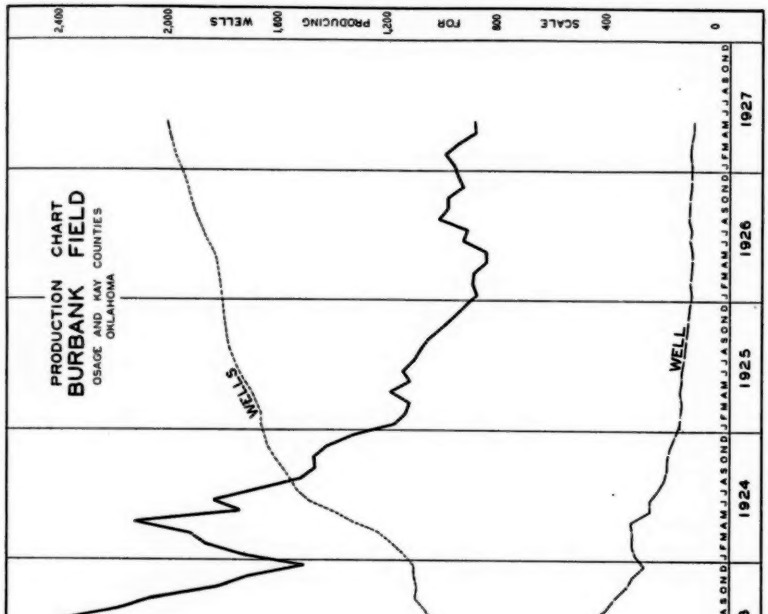
PRODUCTION CHART
BURBANK FIELD
OSAGE AND KAY COUNTIES
OKLAHOMA
SCALE FOR PRODUCING WELLS
SCALE FOR TOTAL PRODUCTION
SCALE FOR AVERAGE PER WELL
TOTAL DAILY AVERAGE PRODUCTION
PRODUCING WELLS
DAILY AVERAGE PER WELL
1920
1921
1922
1923
1924
1925
1926
1927

FIG. 4.

mentioned anticlines which are at the southeast end of the field. This monoclinal condition, deformed by small reversals, is general throughout the territory.

### OIL CONCENTRATION

As far as it has been possible to determine, structural conditions have only a secondary and minor influence in the concentration of oil in this field. The oil sand saturation and the production of wells therefrom seems to be in proportion to the porosity of this sand.

Melcher states:[1]

> The production-porosity curve of the Burbank field shows evidence not only of an interesting relation between the average percentage of pore space of the producing sand and the greatest production for 24 hours of the wells, but also indicates that in the Burbank field the greatest rate of production will be in areas of largest average percentage of pore space, regardless of relation to geologic structures. The curve indicates also that an average pore space of about 13 per cent is the lower limit for commercial production of the producing sand in the Burbank field.
>
> The close relation between average percentage of pore space and maximum production for 24 hours of the wells is largely due to the small ranges of variations in most of the other physical factors, as structure, size of grain, pressure and temperature, specific gravity, and viscosity of the oil.

The highest points structurally in the field are among the places of smallest oil production, and, while more than the usual amount of gas is found with the oil at these places, yet they are not even the most productive portions of the field for gas production. The most prolific portions of the field for oil production are in the northwest part,

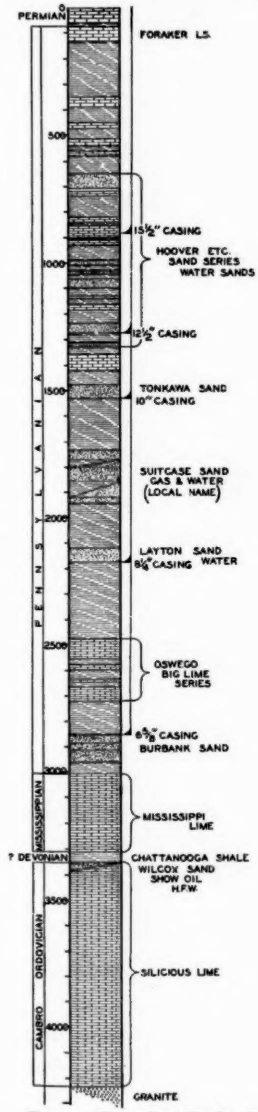


FIG. 5.—Type log, Burbank field, Osage and Kay counties, Oklahoma.

[1] "Texture of Oil Sands with Relation to the Production of Oil," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 (1924), pp. 716–74.

several miles from the highest point structurally, and from 100 to 150 feet below it. The production of the wells changes in a few hundred feet from that of a very large well to a comparatively small one, depending on the porosity of the sand in the two wells. The most porous portions of the sand seem to be in irregular patches, mostly disconnected and in fairly small units, scattered through the whole field, but of large size and more numerous in the northwest portion. This is shown in Figure 3.

On the northern and eastern sides of this field the producing sand grades abruptly into an impervious sandy shale. This change of lithological character has been the primary reason for oil concentration, oil and gas having traveled up the slope in an easterly direction until they could go no farther. Some gas separated from the oil into portions of the reservoir rock, which was not porous enough to admit the oil, this concentration of gas being particularly noticeable on the tops of the two main structures and in places on top of the producing horizon where it had become thickened on top with a fine-grained, almost impervious sand member. Gas also was present in large quantities in the extreme northern end of the field, which is the lowest part of it, the gas being found structurally below the oil where the producing sand was so fine-grained that the oil or water could not penetrate it, but where the pore space was sufficient to allow the gas to accumulate.

Another peculiar feature of this field is that, besides the irregularly spaced and shaped porous portions of the producing sand scattered throughout the field, there is a very porous and productive zone strung along the northeastern extremity of the field. This zone is not more than a quarter of a mile wide and grades in a very short distance into the impervious shale which limits the area of the field in that direction. The writer is not conversant enough with all of the theories of deposition, sedimentation, and cementation of rocks to be sure of the cause of this porosity, but believes that it is probably caused by the leaching out of the calcareous cementing material after deposition by a current of water directed in this course by the impervious nature of the rock to the northeast, and that after this leaching the pore space was filled with oil.

To sum up, therefore, it seems that oil and gas have been trapped in the Burbank field because they could not travel any farther east, and that in so accumulating they were concentrated in the most porous portions of the reservoir rocks. It was, therefore, the impervious barrier on the eastern side of the field and the porosity of the reservoir rock in the field that were the controlling factors in the oil concentration, and not the structural conditions.

# GEOLOGY OF GLENN POOL OF OKLAHOMA[1]

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## ABSTRACT

Glenn pool was the first major oil pool to be developed in Oklahoma. Opened in 1906, it has long since been fully developed in the Bartlesville (Glenn) sand of Cherokee age which has been by far the main producing horizon. Local doming is present and has caused unimportant accumulations in the Mounds ("Wilcox") sand. Accumulation in the Bartlesville, however, is not related to local folding, but is due to the pinching out of the sand body on the eastern or up-dip side of the field.

The writer believes that this pool furnishes very conclusive evidence that its oil was trapped while in transit up the dip from the west. He holds also that the most satisfactory explanation yet advanced for this movement of the oil up the dip is buoyancy arising from the difference in specific gravity between the oil and the associated waters.

## INTRODUCTION

Glenn pool was the first of Oklahoma's major oil fields. The fields in Oklahoma that at some time have had a production peak in excess of 100,000 barrels daily are, in the order of their discovery, Glenn, Cushing, Healdton, Burbank, Tonkawa, and Seminole.

In 1914 Carl D. Smith[2] briefly described the stratigraphy of Glenn pool and published a generalized structure map of the pool and vicinity. Information now available permits revision and correction of this early paper. The writer wishes here to express his appreciation to the members of the geological staff of the Gypsy Oil Company, and especially to Miss Constance Eirich, for helpful suggestions on the subject matter of this paper and in the preparation of the maps and sections with which it is illustrated.

## LOCATION

The main producing area of Glenn pool is located in the northwest part of T. 17 N., R. 12 E., Creek County, Oklahoma. A portion of the pool, with relatively low productivity, extends into the southwest part of T. 18 N., R. 12 E., and is commonly designated the North Extension. At one time this area was the center of much drilling activity, but develop-

[1] Read before the Association at the Tulsa meeting, March 24, 1927. Manuscript received by the editor August 2, 1927.

[2] Carl D. Smith, "The Glenn Oil and Gas Pool and Vicinity," *U. S. Geol. Survey Bull. 541* (1914), pp. 34–39.

ment has now moved westward and at present little consideration is being given to territory east of the field.

### HISTORY

The discovery well in the pool was drilled by Galbreath and Chessley on the Ida Glenn farm near the center of the SE. $\frac{1}{4}$ of Sec. 10, T. 17 N., R. 12 E., in December, 1906. Its initial production was 75 barrels daily from a sand encountered at approximately 1,475 feet, designated then as the Glenn sand and later correlated with the Bartlesville. The site for the test was chosen without knowledge of local geological conditions, and if a location less than one-half mile farther east had been selected a dry hole would have resulted.

The producing area was extended rapidly westward and northward and a production peak of about 120,000 barrels daily was reached in the autumn of 1907, much of the oil, however, being run to storage. The peak of marketed production was reached in 1908 at approximately 80,000 barrels daily. The present production is nearly 10,500 barrels daily from approximately 4,000 wells. The recovery per acre has varied widely in the field. A few leases have produced to date in excess of 40,000 barrels per acre, but the average for the pool is less than one-fourth that amount.

Long since completely drilled to its principal producing sand, the field is now of interest chiefly in a historical and scientific way. However, the writer believes that only a minor fraction of the original oil content has been removed by production methods of the past and present, and that the pool is especially well adapted for additional recovery by the application of pressure or flooding methods. On this account the pool may some day stage a comeback that will contribute an item of importance to production statistics.

### STRATIGRAPHY

#### PENNSYLVANIAN

In Figure 1 is shown a generalized columnar section for the Glenn pool area. Pennsylvanian rocks are at the surface and beds of that age extend downward to a depth of approximately 2,000 feet. Subdivisions of this part of the section are not based on an intensive and systematic study of well cuttings, but represent merely the commonly accepted terminology of geologists and drillers familiar with this area. However, the writer believes that the nomenclature is essentially correct, though there is a question as to whether the "Big lime," so called by the drillers, is really the equivalent of the Oologah at its type locality. The reader should bear in mind that the field was practically drilled up twenty years ago

## COLUMNAR·SECTION·FOR·GLENN·POOL·AREA

| System | Formation | Member | Thickness in feet |
|---|---|---|---|
| PENNSYLVANIAN | Undifferentiated | | 750 |
| | Oologah Ls. ("Big Lime") | | 35 |
| | Labette shale | | 125 |
| | Fort Scott ("Oswego" Lime) | | 20 |
| | Cherokee 1000' | Red Fork s.s. | 15 |
| | | Bartlesville | 100± |
| | | Tanaha | 20 |
| | | Dutcher | 25 |
| | Unconformity | | |
| MISSISSIPPIAN | Mississippi Lime | | 230 |
| | Chattanooga Black shale | | 60 |
| | Unconformity | | |
| ORDOVICIAN | Simpson | Mounds (wilcox) Sd. | 20-50 |
| | | Tyner Fr. | 60 |
| | | Burgen s.s. | 20 |
| | Arbuckle Ls. | | 500± |

FIG. 1

and that well logs and other data were recorded at that time most inadequately. In most cases sand records only were preserved, and the saving of well cuttings was unknown.

### MISSISSIPPIAN

In recent years several old wells throughout the field have been deepened from the Bartlesville sand and several new deep tests have been completed. The logs and cuttings from these sources permit rather satisfactory identifications of the stratigraphic units. The classification of the pre-Pennsylvanian rocks given in Figure 3 is based on a study of well cuttings by Charles Ryniker, of the Gypsy Oil Company.

Unconformably under the Pennsylvanian are about 300 feet of Mississippian limestone and shale beds. The limestone is probably the equivalent of the Mayes limestone of the Hunton arch, and the underlying black shale is referred to the Chattanooga. In several wells in this general area a few feet of calcareous shale is present between the Chattanooga and the overlying lime. This shale may be a representative of Kinderhook age, but the writer has not felt justified in including it as such in the generalized section.

### ORDOVICIAN

Unconformably underlying the Mississippian are Ordovician beds which have been penetrated by the drill about 600 feet. These are referred to the Simpson and Arbuckle formations of the Arbuckle Mountain section. Presumably the Arbuckle limestone rests upon pre-Cambrian granite, but according to the writer's knowledge the nearest test to reach granite is 8 miles northwest of the pool. This test, which is located in Sec. 22, T. 19 N., R. 11 E., entered granite after passing through about 600 feet of Arbuckle lime.

### SURFACE STRUCTURE

Unfortunately no structure map based on observations on beds exposed at the surface is available to the writer. Perhaps no such map exists. Data were available for subsurface maps of the area before petroleum geologists were employed in Oklahoma, therefore no economic purpose would be served by a map of the surface structure. It is well known, however, that the surface structure of the general area is a monoclinal dip to the west at a rate of about 50 feet per mile. Surface maps of areas adjacent to the pool show local folds, chiefly of an anticlinal or nose type, plunging to the west. Structures showing closure at the surface are rare. There is little doubt that throughout the greater part of the pool, local surface

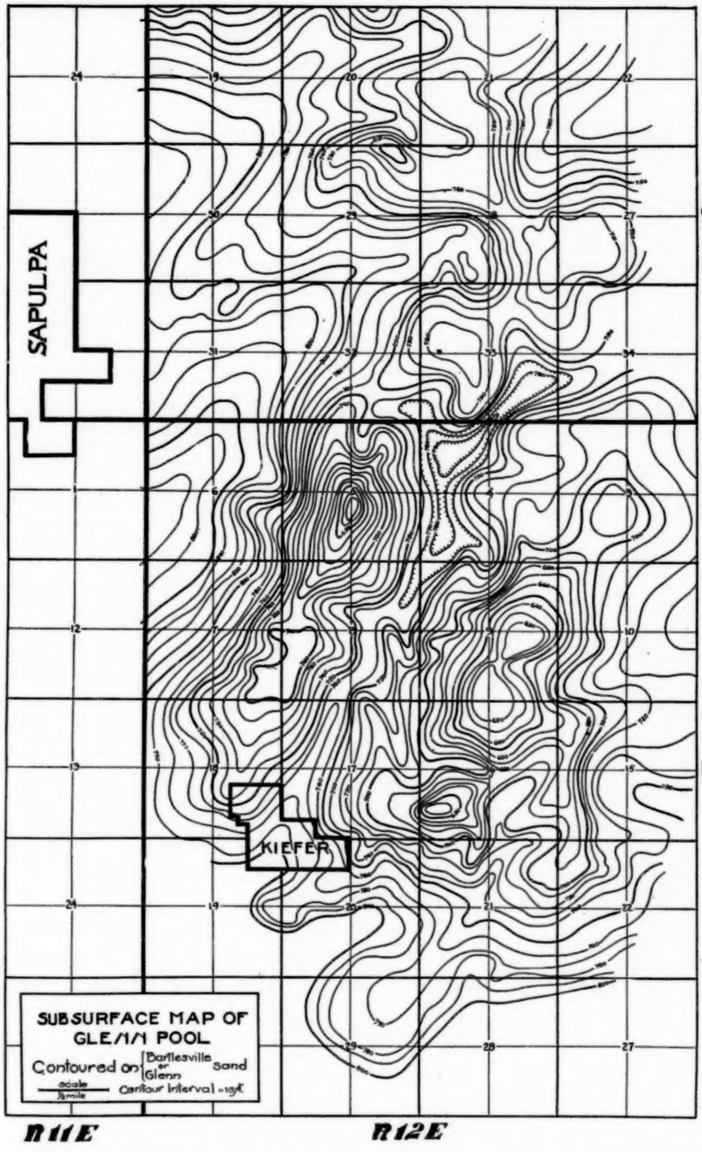


FIG. 2.—Subsurface map of Glenn pool, Oklahoma, contoured on Bartlesville sand below sea-level.

structures consist of minor variations from the regional dip, although there is a possibility that careful work with planetable control would show closed surface structures corresponding to the domes in Figure 3.

### SUBSURFACE STRUCTURE

Because of the fact that by far the greater part of the well logs of Glenn pool consists of sand records only, no attempt was made to construct a subsurface map on a higher datum than the top of the Bartlesville sand (Fig. 2). Contours on the top of that sand show considerable irregularity and several areas of closure when contoured with a 10-foot interval. Only a part of the apparent structure shown in Figure 2 can be attributed to folding. The rest is due to irregularities of deposition, and particularly to the pinching out of the sand body to the eastward. Undoubtedly a map on the base of the Bartlesville would be a truer guide to actual structure, but so few wells, particularly in the western part of the field, definitely penetrated the full thickness of the sand body that it is impracticable to construct such a map. Doubtless the closure shown in Sec. 5, T. 17 N., R. 12 E. represents actual doming of the strata, and probably that in Sections 9 and 16 as well.

It is seen that the producing area in the Bartlesville sand shows little if any relation to local folding, since it extends indiscriminately across anticlines and synclines. Nor are the more prolific areas restricted to the areas high structurally or in any definite relation to them. The areas of high recovery are undoubtedly coincident with areas of relatively high porosity in the sand body. As will be shown later, there is good reason to believe that the accumulation in the Bartlesville horizon would have occurred if no local folding had been present.

The structure map on the top of the Mounds ("Wilcox") sand is based on far fewer well records than is the case with the Bartlesville sand map, but the records used are the result of later development and are more reliable. The writer believes that the structure shown in Figure 3 is a fairly accurate representation of the structure of the Ordovician beds, and that no other important structures are present. Pronounced doming is present in Sec. 5, T. 17 N., R. 12 E., and along the boundary of Sections 9 and 15. It may be noticed that in these two areas the structures appear to be reflected in the Bartlesville also. Several tests have found production in the Mounds sand on each of these structures, as well as on those in Sections 27 and 29. Referring to Figure 3, the shaded parts show the extent of the development in the deeper sand. However, production from the Ordovician has been disappointing and of little importance. The ini-

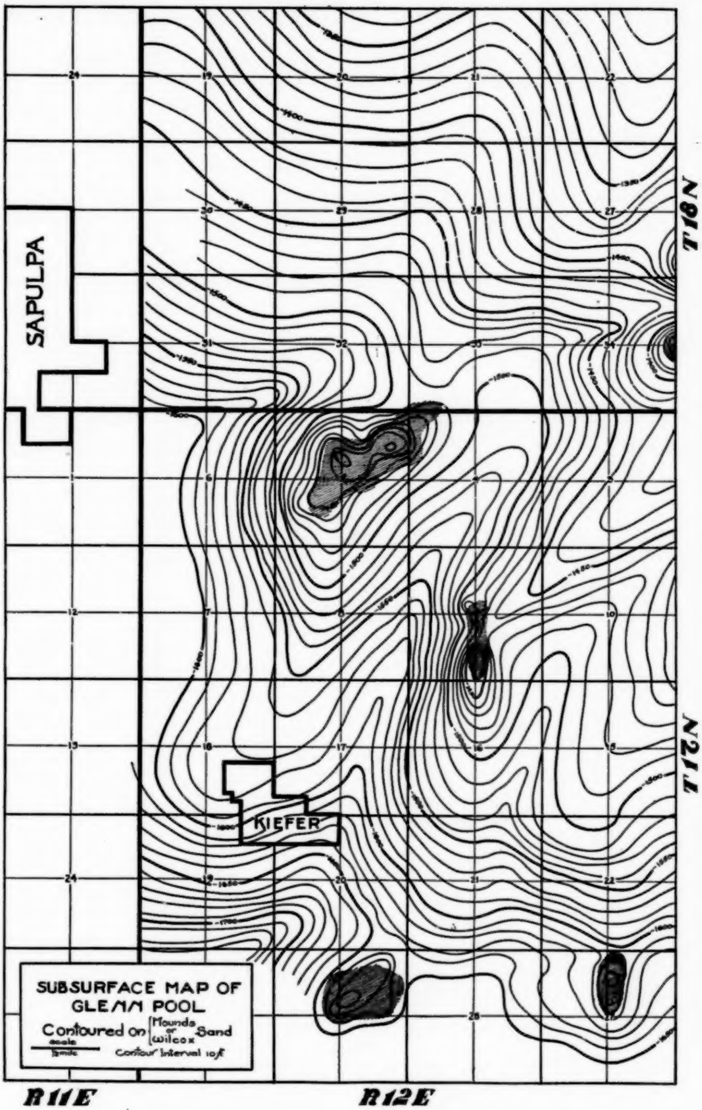


FIG. 3.—Subsurface map of Glenn pool, Oklahoma, contoured on "Wilcox" sand below sea-level. Shaded portions are areas of "Wilcox" production.

tial production from the wells has averaged 100 barrels daily or less, and has not been very profitable even at the comparatively shallow depth at which the pay is found. Moreover, the oil recovered from the Mounds sand is of low gravity and in all respects inferior to the Bartlesville oil. It may be noticed by referring to Figure 1 that an opportunity was probably afforded for the lighter oil constituents to escape from the Mounds during the period of erosion represented by the unconformity at the top of the sand.

The heavy oil from the Mounds here is an exception to the general rule throughout the northern Mid-Continent that Ordovician oil is higher grade than that found in the lower Pennsylvanian.

### RELATION OF ACCUMULATION TO STRUCTURE

There is no particular problem calling for discussion in the case of the Mounds production. It is restricted to the closed domes scattered through the area, as is always the case with Mounds sand production. The case of the accumulation in the Bartlesville sand is quite different. Oil is present on the local domes and in the synclines between them as well. The writer holds that there is every reason to believe that the pool would have had essentially the same extent and productivity if no local doming or folding were present. All evidence points to a conclusion that accumulation here is due to the pinching out of the sand body to the north, northeast, and east.

In Figure 4 is shown an east-west cross-section through the main producing area. In the heart of the pool and for many miles to the west and south the thickness of the Bartlesville sand exceeds 100 feet. At or near the eastern limits of production the sand thins practically to zero in a distance of one or two miles. Since the interval from the base of the sand to the "Oswego–Big lime" above is nearly constant, it is clear that the sand thins from the top. There is an interfingering of sand and shale with the shale content increasing eastward to complete pinching out of the sand. The writer's interpretation of the situation calls for a southern or western source for the sand, which was poured out on the sea bottom and distributed by wave action. In the area east of the pool, the sea in Bartlesville time was too deep for the waves to drag the bottom and thus move the sand along.

The thickness and distribution of the Bartlesville sand body in the pool and its vicinity is shown by an isopach map (Fig. 5) in which the shaded portion is the producing area in the Bartlesville. It will be noticed that the accumulation has adjusted itself in a striking way to the configu-

ration of the sand body along the eastern margin of the field. No production of importance was ever developed where the sand thickness is less than 25 feet. West and south of the pool the sand is present for many miles with a thickness quite uniformly in excess of 100 feet, but it carries salt water and is referred to by the drillers as the "salt" sand. Along the western margin of the pool the oil conforms to a water level of approximately 950 feet below sea-level.

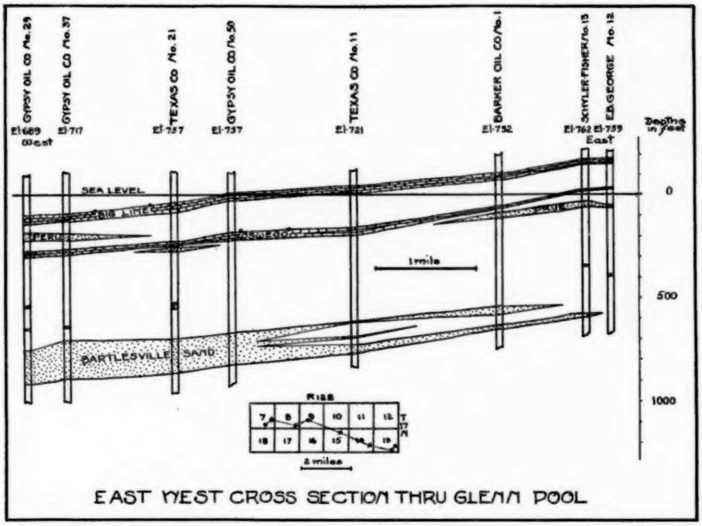


FIG. 4.—West to east cross-section through Glenn pool, Oklahoma, showing pinching sands. For relation to producing area, see Figure 5.

CAUSE OF ACCUMULATION

The writer considers that the situation in Glenn pool provides a remarkably strong case for the proponents of the theory that lateral migration has been an important factor in many, if not most, of our major oil fields. Certainly lateral migration is the most logical explanation of the accumulation here. There appears to be no reason why oil should ever have been generated in exceptionally large quantities locally. Local structures are present, but they are present in equal number and kind in the townships to the south and west for many miles, but on the latter no Bartlesville production of importance has been found, although the area

has been intensively tested. Although no reason can be advanced for the generation of exceptional quantities of oil at Glenn pool, the situation is ideal for trapping oil in transit up the dip from the west.

In Glenn pool the situation seems to be similar in all essential respects to barren territory to the south and west, with the one exception that

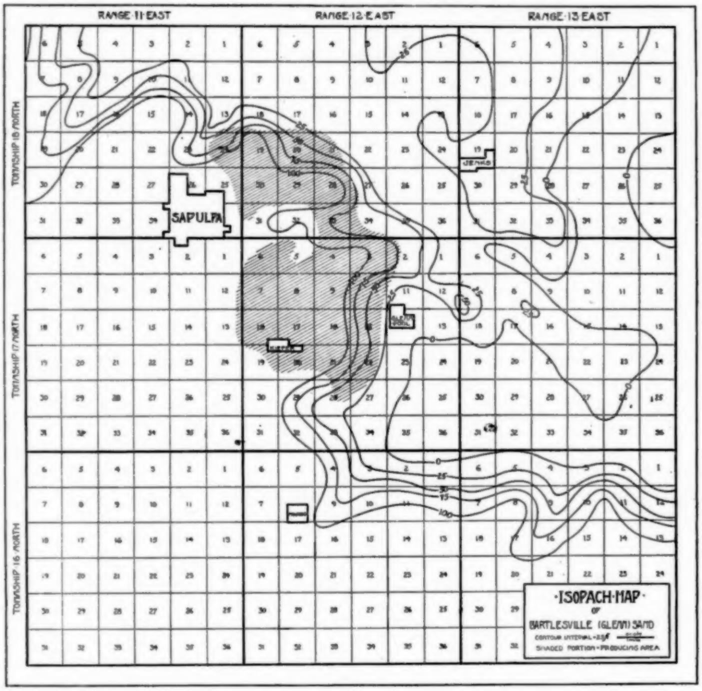


FIG. 5.—Isopach map of Bartlesville sand, Glenn pool, Oklahoma

there the Bartlesville sand pinches out, and there an oil field has resulted. As the pinching out of a sand body may not be offered as a reasonable explanation for generating oil, but as the pinching sand affords an excellent trap, the writer feels fully justified in asserting that the trapping action has been the dominant one. It may be true that many pools of minor importance have been fed from local sources only, but when considering pools with peaks in excess of 100,000 barrels daily, where total

production mounts into hundreds of millions of barrels, it is comforting to the writer to call generously upon lateral migration. In passing, it seems worthy of comment that in this locality, in the case of the Mounds sand, which is continuous to the north and east and therefore open to migration, the oil accumulation is limited to traps formed by local doming.

Moreover, the situation at Glenn pool, in the writer's judgment, offers some support to the oldest of theories of oil migration, namely, that it moves up the dip due to buoyancy arising from the difference in specific gravity between the oil and the associated water. The migration may never have taken place at a rate that could be detected in a few days or weeks in laboratory experiments. There is no convincing evidence that there has been movement of the water either up or down the dip, carrying oil with it. The chemical character of the waters in the sands of the Glenn pool area is opposed to any reasonable theory of circulation. The waters are brines, and the concentration of total solids in them is several times that of sea water, which above all does not suggest infiltration of meteoric waters from the outcrops. Due to differences of gravity there is a constant pressure tending to drive oil up the dip of inclined strata when it is associated with water. If the action took place so slowly that no oil particle ever responded by advancing more than an inch a year there is no inadequacy of the time factor in accounting for Glenn pool.

# CRINERVILLE OIL FIELD, CARTER COUNTY, OKLAHOMA[1]

SIDNEY POWERS[2]
Tulsa, Oklahoma

## ABSTRACT

The Crinerville oil field, near Brock, Carter County, Oklahoma, occurs on a surface anticline in Pennsylvanian strata on the west side of, and faulted against, the Criner Hills. The reverse dip of 15° on the northeast side of the anticline disappears under a large part of the anticline in shales within 900 feet of the surface. Production comes from Pennsylvanian oil sands which overlap a truncated portion of the original Criner Hills of Ordovician limestone, now buried at a depth of more than 1,000 feet. The oil originated in the Pennsylvanian shales, and a small quantity migrated laterally into the Ordovician. The field was opened in January, 1922, and has produced between 1,000 and 1,500 barrels a day ever since. The total production to June 30, 1927, was slightly more than 2,300,000 barrels.

## INTRODUCTION

### LOCATION

Crinerville oil field, named from a schoolhouse, is 2 miles southeast of Brock and 7 miles southwest of Ardmore. The field extends southeast from the center of the south line of the SW. $\frac{1}{4}$ of Sec. 17, through the E. $\frac{1}{2}$ of Sec. 20 and the E. $\frac{1}{2}$ of Sec. 28, to the center of Sec. 34, T. 5 S., R. 1 E. By July, 1927, $5\frac{1}{2}$ years after the discovery, 139 oil wells (7 now abandoned), 3 gas wells (2 now abandoned), and 46 dry holes had been drilled. The depth of production ranged from 845 to 2,200 feet. The initial production averaged about 50 barrels, and the settled production, 15 barrels.

This field is located 15 miles southeast of the southeastern end of Healdton and 10 miles southeast of the southeastern extension of Hewitt. It lies parallel to the Criner Hills in a belt from one-quarter to three-quarters of a mile from their southwestern flank. It is 15 miles south of the Arbuckle Mountains.

### GEOLOGY

Geologically, the field is located on an inlier of the Glenn and Hoxbar formations of Pennsylvanian age, surrounded on the west and south, and

[1] Presented by title before the Association at the Tulsa meeting, March 26, 1927. Manuscript received by the editor July 28, 1927. Published by permission of the Amerada Petroleum Corporation.

[2] Consulting geologist, Amerada Petroleum Corporation, Box 2022, Tulsa, Oklahoma.

in part on the north, by the unconformable Trinity sand of Cretaceous age. The Pontotoc formation of Permian age rests on the Glenn north of the field. The Criner Hills, against which the Glenn formation is downfaulted, are a fragment of the ancient Criner Hills, or possibly of the ancient Wichita Mountains, and consist of complexly folded and faulted Ordovician limestones, bounded on the east by faulted fragments of most of the formations known in the Arbuckle Mountains, 15 miles to the north. Production comes from sands within the Glenn formation which overlaps the ancestral Criner Hills.

The areal geology has been mapped by Taff,[1] Goldston,[2] and Tomlinson.[3] Other pertinent geological reports are by Birk,[4] Girty and Roundy,[5] Moore,[6] and Bullard.[7] The accompanying map (Fig. 1) is after Tomlinson.

## DEVELOPMENT

The Crinerville anticline appears to have been known since about 1916, but neglected as a possible oil prospect. It was discovered by the Amerada Petroleum Corporation about June 1, 1920, and the leasehold was secured in 1920 and 1921, giving a solid block except for fee lands of Westheimer & Daube and F. E. Watkins.

The discovery well, Sammy Baptiste No. 1, was located by E. L. DeGolyer near the center of the SE. $\frac{1}{4}$ of Sec. 20, on the west side of the small closure in contours of the surface geology shown in Figure 2. It was commenced in December, 1921, and the first sand was struck at 1,321 feet, January 15, 1922. The first sand was only 4 feet thick and good for about 50 barrels. A second sand at 1,371 feet was good for 20 barrels; and

[1] J. A. Taff, "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains," *U. S. Geol. Surv. Prof. Paper 31*, 1904.

[2] W. L. Goldston, Jr., "Differentiation and Structure of the Glenn Formation," *Amer. Assoc. Petrol. Geol. Bull.*, Vol. 6 (1922), pp. 5–23.

[3] C. W. Tomlinson, unpublished map dated April, 1926; also *Oklahoma Geol. Surv. Bull. 40*, 1927.

[4] R. A. Birk, "The Extension of a Portion of the Pontotoc Series around the Western End of the Arbuckle Mountains," *Amer. Assoc. Petrol. Geol. Bull.*, Vol. 9 (1925), pp. 983–89.

[5] G. H. Girty and P. V. Roundy, "Notes on the Glenn Formation of Oklahoma, with Consideration of New Paleontologic Evidence," *Amer. Assoc. Petrol. Geol. Bull.*, Vol. 7 (1923), pp. 331–49.

[6] R. C. Moore, "The Relation of Mountain Folding to the Oil and Gas Fields of Southern Oklahoma," *Idem*, Vol. 5 (1921), pp. 32–48.

[7] F. M. Bullard, "Geology of Love County, Oklahoma," *Oklahoma Geol. Surv. Bull. 33*, 1926; Geology of Marshall County, *Idem, Bull. 39*, 1926.

a third, from 1,564 to 1,629 feet, made 90 barrels. This well flowed from the third sand for 3 years before it was put on the pump. These three are the principal sands in Section 20, the wells being completed so that they

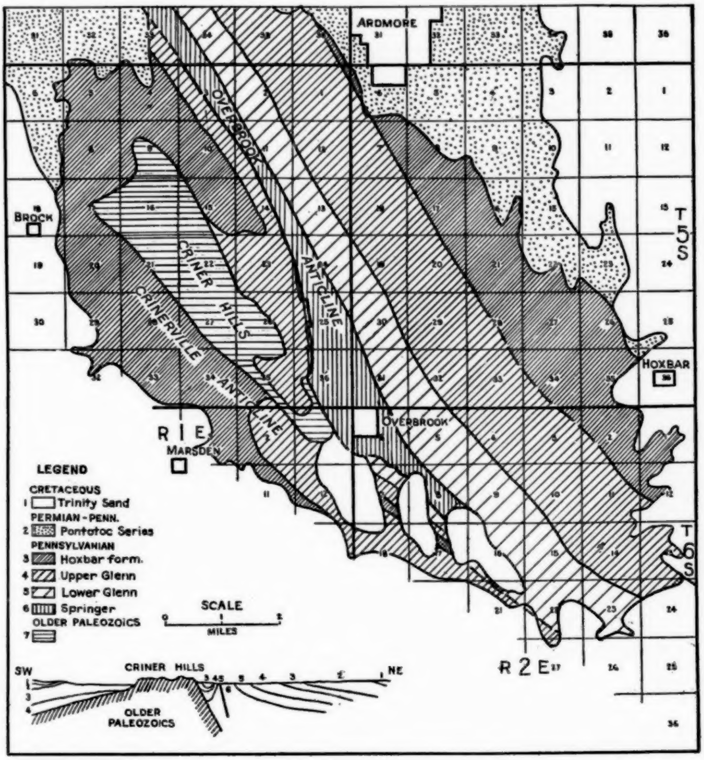


FIG. 1.—Areal geological map of the Criner Hills, showing the relation of the Crinerville anticline to the horst of older rocks. (Geology by C. W. Tomlinson, Amerada Petroleum Corporation, and others.)

produce either from the first two together by setting a perforated liner through the first sand, or else from the third sand. Two deeper oil sands, called the fourth and fifth, occur locally on the northern and western flanks of the anticline.

Soon after the discovery of the field, Westheimer & Daube completed

a well in Section 21 in the top of the Ordovician, with "sand" at depths ranging from 1,585 to 1,682 feet, flowing 250 barrels. The Pennsylvanian sands were not productive. Two offsets to this well made 600 and 1,100 barrels, respectively; but the well highest in the producing horizon drained

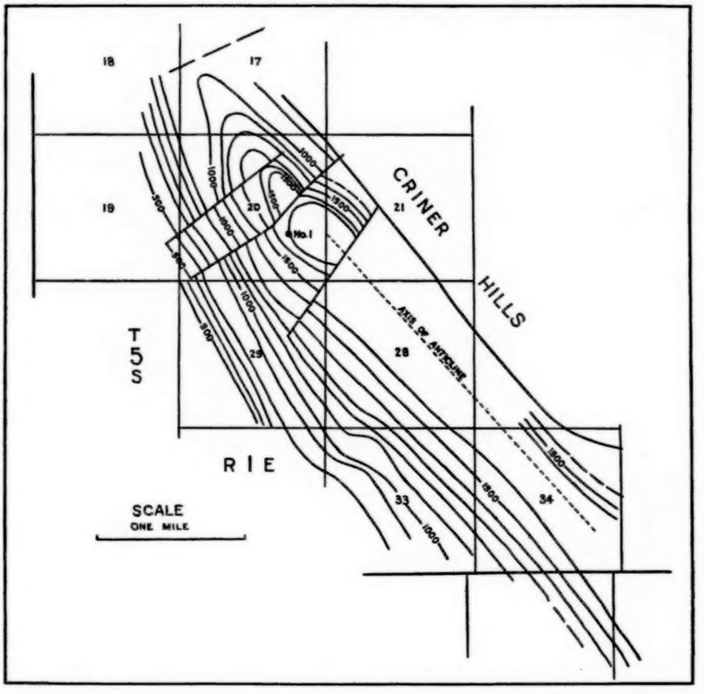


FIG. 2.—Structure contours, above sea-level, of the surface geology, Crinerville anticline. Contour interval, 100 feet. Datum, sea-level. The location of the discovery well is shown. (Geology by R. A. Birk and C. J. Wohlford, for the Amerada.)

the oil, and all three wells declined rapidly and were abandoned within a year. As the oil was exhausted the sulphur water increased. With the exception of one gas well, other near by wells drilled into the Ordovician found only sulphur water with more or less sulphur gas.

The field was a disappointment until large wells were found in the north half of Section 20 in 1923. By 1924, production seemed to be defined by dry holes. A hand drill was used to locate the axis of the anticline

at the surface in Sections 28 and 27, and a well was drilled on the Clay farm, in the center of the west line of the NE. ¼ of Sec. 28 on this axis.

Oil was found in a sand from 1,074 to 1,083 feet in Clay No. 1, on October 27, 1924. The well flowed 230 barrels steadily and opened the extension in Section 28. The main producing horizon is the second sand. A few wells yield oil from a sand intermediate between the first and second of the original field, but not present there.

A second extension of production, in Section 34, near the center of the section, was made in May, 1925, but the wells are very small.

### TOPOGRAPHY

Topographically, the eroded peneplain of the Criner Hills has an elevation of 1,000 feet above sea-level, or 150 feet above the secondary peneplain on the Pennsylvanian and younger rocks. The dissection of the latter peneplain has produced a relief of 100 feet.

Vegetation is an excellent guide to geology. Short grass only grows on the barren Ordovician limestone hills. The Pennsylvanian shales support tall grass, and ridges formed of the few limestone beds are marked by rows of bushes and tall weeds. The Permian and Cretaceous sandstone are covered with a dense growth of "blackjack" oak.

### ACKNOWLEDGMENTS

The writer is indebted to R. A. Birk and Miss Dollie Radler for assistance in preparing this paper, and to B. H. Harlton for paleontological determinations. C. W. Tomlinson, who has made a careful study of the Glenn formation, has kindly permitted the use of his determinations and areal map.

### GEOLOGIC HISTORY

Within the Arbuckle Mountains there are exposed pre-Cambrian granites and the well-known section of Paleozoic sedimentary rocks extending upward through the Caney shales of Mississippian age and through part of the Glenn and other formations of Pennsylvanian age. The most important group of rocks is that of the Ordovician limestones. Structural conformity marks the entire pre-Pennsylvanian section when considered as a whole, but there is an unconformity above the Hunton group (Devonian at the top) which marks undulating folding of the entire region. This folding is known best on the north flank of the Arbuckle Mountains, in the Seminole and other oil fields.

Fragments of the formations in the Arbuckle Mountains, from the Arbuckle at the base through to the Woodford chert at the top, are ex-

posed in the Criner Hills, the older rocks being on the southwest side. Faulting has masked the relationship of different formations, but structural conformity is supposed to exist to the top of the Woodford. Strata representing all the members of the Glenn formation as defined by Goldston occur on the east side of the Hills, but the base of the section is not exposed. Subsequent work has led to a reclassification of this section: Springer formation at the base, Otterville (Wapanucka) limestones, Glenn formation, consisting of Cup Coral and Deese members and Hoxbar formation, at the top, overlain farther west and underground by sedimentary rocks of Upper Cisco age.[1]

On the west side of the Criner Hills, the wells at Crinerville start in the Deese member of the Glenn on the axis of the anticline and in the Hoxbar formation on the flanks, and find Ordovician limestones below the Deese. Cuttings from wells show that the buried Ordovician rocks are Arbuckle on the east; but both the Simpson formation and Viola limestone may occur under the field. This unconformity proves that the folding and faulting of the ancestral Criner Hills took place after the deposition of the Springer formation and before the deposition of the Deese member of the Glenn. The writer believes that the uplift is a part of the ancestral Wichita Mountains, and that these mountains were once continuous as far southeast as Gainesville, Texas, but that granite was exposed in a few places in the portion now concealed by Permian and late Pennsylvanian rocks.

Coarse conglomerates occur in and directly beneath the Otterville limestone and in the Cup Coral member of the Glenn on the east side of the Criner Hills,[2] and they date the uplift of the ancestral Criner Hills and Wichita Mountains. The pebbles are largely of Ordovician limestone; there are none of granite because whatever granites were exposed in the Wichitas were too far distant. It is evident that these conglomerates came from the near by ancestral Criner Hills and the area to the west—the Wichita Mountains. Finally this region was leveled and submerged by the upper Deese. Conglomerates have not been found at the unconformity under Crinerville on the west side of the Hills. Arkose occurs in conglomerates in the uppermost Deese and in the Hoxbar in exposures east of the Criner Hills.

Both the northern Arbuckles and the Wichitas were folded early in

[1] Sidney Powers, "Age of the Folding of the Wichita, Arbuckle, Ouachita Mountains of Oklahoma and Llano Burnet and Marathon Uplifts of Texas," *Geol. Soc. Amer. Bull.*, Vol. 38, 1927 (in preparation).

[2] Personal communication from C. W. Tomlinson.

the Pennsylvanian. Refolding and faulting occurred several times during the Pennsylvanian and at the close of this period. The ancestral Criner Hills were faulted again late in the Pennsylvanian. These faults on the west and north sides of the present Hills were normal with a downthrow on the west and north of at least 1,000 feet. After this faulting there was compression which squeezed the plastic Pennsylvanian shales against the resistant block of limestone and made the anticlinal fold seen at the surface at Crinerville. This folding probably occurred at the time the Glenn basin at Ardmore was compressed into long anticlines and synclines.

Sedimentation recommenced before the Permian. The Pontotoc arkoses and conglomerates were deposited late in the Pennsylvanian or early in the Permian on the flanks of the Arbuckles and on the northeastern flank of the Wichitas, the ancestral Healdton, Hewitt, and Criner hills. Permian Red beds overlie the Pontotoc. Another uplift folded the Red beds into gentle flexures, and some of the anticlines of this generation overlie the older ones. The folds in the Red beds cannot be mapped with satisfaction because of cross-bedding and scarcity of exposures. These sandstones and shales covered an area of considerable relief in which the hills were anticlines. It seems remarkable that these hills are not reflected more distinctly because there are only about 300 feet of Red beds under Healdton, and 2,400 feet under an area 3 miles north of this field.

Trinity sand, of Lower Cretaceous age, was deposited over most of southern Oklahoma, and probably over the Criner Hills. The character of folding of the Cretaceous is indicated in the Preston anticline of Marshall County, yet the Cretaceous beds do not reflect folding in the older rocks in Cooke County, Texas.

Later uplift has elevated the peneplain of the Arbuckles and the antecedent Washita River. Still later uplift has elevated the lower peneplain on the softer rocks. It is difficult to connect the anticlinal hills of Healdton, Hewitt, Velma, and other fields with differential uplift in post-Cretaceous time because most of the anticlines in the Mid-Continent region have been hills at one or more times since the Ordovician.

## STRATIGRAPHY

### EXPOSED BEDS

The Crinerville anticline was mapped on limestone and sandstones of the Hoxbar formation on the flanks and the Deese member of the Glenn on the top. According to stratigraphic measurements by R. A. Birk and C. J. Wohlford for the Amerada, the thickness of the Hoxbar, measured from

the base of the lowest to the highest bed exposed, is 1,180 feet in Section 20 and 1,250 feet in Sections 28 and 29, and the thickness of the Deese exposed in Section 34 exceeds 200 feet. The dip on the southwest flank is about 15 degrees and on the northeast flank 20 degrees. The thickness of the section is difficult to measure on account of faulting, but these measurements are confirmed by well logs.

### UNEXPOSED BEDS

Sammy Baptiste No. 1, the discovery well, started in the limestone at the base of the Hoxbar, found a water sand at 400 feet, and a gas sand at 1,000 feet. This section is similar in all the wells in the field, but there are generally at least two water sands and some sandy shales and thin limestones. Several sands and thin limestones between 1,000 and 1,063 feet which produce in two wells in Section 17 are called the "heavy oil series" because they carry a little oil of 20° Bé. gravity. These sands are separated by 240 feet of shale from the main oil series below. The first and second oil sands, at a depth of more than 1,300 feet, are 20 to 50 feet apart, and the third is 150 feet or more below the second. The first thick limestone is, as a rule, the Ordovician, and it may be found at any depth below the heavy oil series, although as a rule it is covered by the first and second sands. Away from the field a section of more than 1,000 feet of shale and water sands has been found below the third sand. One well in Section 28 on the edge of production was drilled in solid limestone from 1,492 to 3,930 feet. D. K. Gregor and V. V. Waite in private reports described this limestone as Simpson.

Correlations are made tentatively on the heavy oil series and definitely on the first oil sand, but they are very difficult to make, even though all wells are drilled with standard tools. The sands are not overlain by a hard cap rock or "shell," and in some places are not recognized. In Section 21 and elsewhere the sands merge into brown shales recorded in the well logs as "Red beds."

Changes in thickness and composition of the sands, both of the water sands above and oil sands below, are rapid. The oil sands were deposited by progressive overlap on the older, truncated limestones, and the sands and shales filled the irregularities on the erosional surface. The large divisions of the section, thick shales above and alternating shales and sands below, do not vary greatly in thickness, but the number of water sands increases away from the field so that correlation for a long distance on lithologic grounds is impossible.

## CONDITIONS OF DEPOSITION

The ancestral Criner Hills constituted a land area of low relief at the time of deposition of the upper part of the Deese over them. The brown or red shales into which the sands merge on the east are believed to have been deposited near or above sea-level and to represent the muds exposed to areal oxidation. Similar relationship of sands and red or brown shales are very common on the anticlines in the Mid-Continent region and may also be observed in the oil mines of Pechelbronn, France. Oil is seldom found where the sand merges into brown shale.

## SURFACE STRUCTURE

Folds in the Paleozoic section of southern Oklahoma are essentially of the anticlinal type, as throughout the Mid-Continent region where the anticlines are elevated from a more or less common level without corresponding synclines with closure. The axes of the folds extend uniformly northwest and southeast. Crinerville is one of these folds, but it might be termed a "geological accident" because of its superposition over truncated Ordovician limestones and its faulted relationship to the present Criner Hills with downthrown beds dipping steeply toward a normal fault, and also because the fold dies out at a shallow depth. The other anticlines are either sharp folds in a thick Pennsylvanian section or else broad folds with subsidiary domes and saddles over buried hills of Ordovician limestone, the detailed structure reflecting buried topography.

The surface-structure contour map of the anticline (Figure 2) is based on planetable mapping of limestone outcrops. In order to confirm the presence of a northeast dip where there are no exposures, several excavations were made in the Pennsylvanian shales at the faulted contact with the Criner Hills, and two lines of holes were drilled across the axis of the anticline. Instead of drag dips, the shales dip steeply to the northeast at the fault plane.

The anticline is an asymmetrical fold which starts in Sec. 2, T. 6 S., R. 1 E., as a nose cut off on the south by a fault against the Criner Hills. The axis runs parallel to the fault at the west side of the Criner Hills as far as the center of the west line of Sec. 17, T. 5 S., R. 1 E., where it is cut off by a fault. North of this point the limestones bend broadly around the Criner Hills and do not seem to be affected by the Crinerville fold. The length of the fold is 4 miles.

Closure was not found along the anticlinal axis, though there is almost a closure in the southeast corner of Section 20. In Section 34 the axis

plunges more steeply to the northwest and older beds are exposed at the surface.

Faulting is very common at the surface, as will be described later. The minor faults die out at a shallow depth.

### SUBSURFACE STRUCTURE

The structure on the second oil sand is shown in Figure 3. There is a general southwesterly dip, with high areas in sections 20, 28, and 34 separated by synclines. The cross-faults at the surface (Fig. 2) are not clearly shown on this horizon, but those with the largest throw may extend to this depth. Another fault is shown in sections 21 and 17 parallel to the Criner Hills because the Ordovician was found in the easternmost well 400 feet higher than in the offset on the west in Section 21. The correlations are too unsatisfactory to prove that this fault cuts the Pennsylvanian.

The eroded and folded surface of the Ordovician (Fig. 4) resembles the structure of the second sand, but the west slope is much steeper and there is a more pronounced flattening in the E. ½ of Section 20. The Pennsylvanian sands overlap this surface, and each has a separate shore line against it (Fig. 5). The highest, or first, sand has its shore line on the eastern edge of the field in Sections 28 and 34. Low hills and valleys, with a local relief of 50 feet or less, have been found on the surface of the limestone, and some of the hills project above the pay sand in the southeast corner of Sec. 20, the SE. ¼ of Sec. 28, and center of Sec. 34 (Fig. 3). The larger valleys underlie those shown on the second sand map. This relief is in places so local that both in Section 28 and in Section 20 a five-spot well in the center of a rectangle of producers 400 feet by 460 feet apart was a dry hole because the lime projected above the level of the sand.

The distribution and structure of the oil sands which rest against and over the Ordovician unconformity are determined by the configuration of this surface in upper Deese time. Explanation of the irregularities in the surface of the Ordovician is found in the lithology of the older rocks. The folding which made the anticline in the upper beds tilted all the rocks toward the southwest at an angle of about 10°.

### FAULTING

The gently curved fault line which separates the Pennsylvanian and Ordovician at the surface slopes away from the Hills at an angle of about 70°. The sinuous plane in many places follows the strike of the steeply

tilted limestones, and this fact makes the contact appear as though the Pennsylvanian shales had slid away from steep-sided limestone hills.

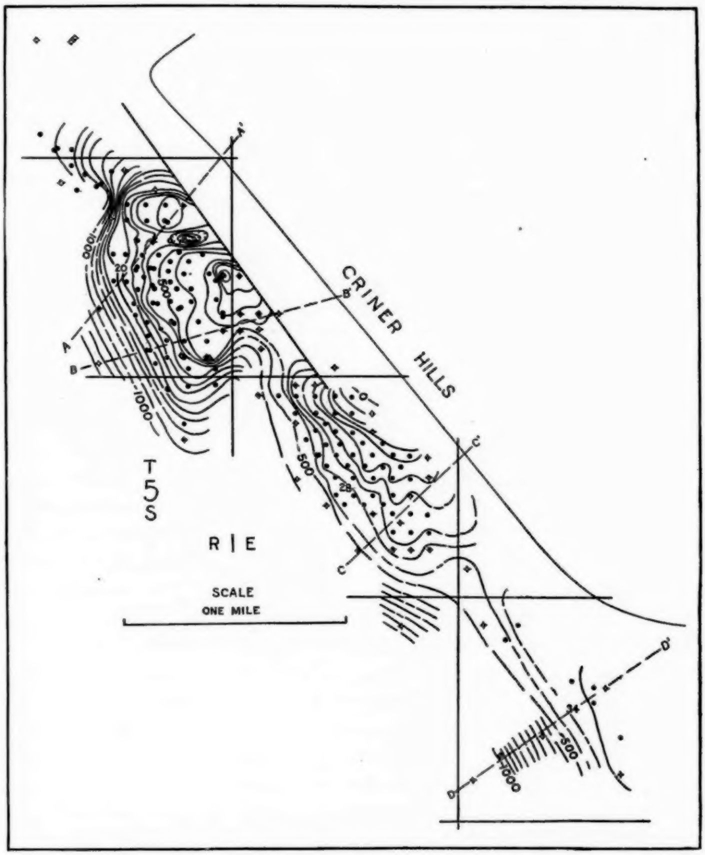


FIG. 3.—Structure contours of the Crinerville oil field, below sea-level, on the "second" oil sand. Contour interval, 50 feet. Location shown of sections *A–D* of Figure 5. The anticline at the surface cannot be recognized at this horizon, depth 900–1,800 feet. (Geology by Dollie Radler, for the Amerada.)

Drilling has, however, proved a major fault with a drop of about 1,000 feet. The fault appears to turn at right angles in Sec. 17 and runs northeast; farther east it makes two more similar turns to encompass the north

end of the hills, or else there are two sets of faults.[1] It is possible that at these corners short faults extend between the Pennsylvanian outcrops, and therefore cannot be found.

An explanation of these sharp turns is that intersecting sets of faults were formed when the Hills were folded in early Pennsylvanian time and that right-angled blocks gave way simultaneously in the later faulting so that the trace of the fault in the Pennsylvanian actually turns sharp angles without cross-fractures. In support of this view it may be pointed out that the cross-faults in the present Criner Hills (marked by valleys) do not cause offsets in the trace of the major fault plane.

South of the oil field the major fault turns and extends north and south and cuts off the anticline in Secs. 1 and 2, T. 6 S., R. 1 E. Still farther south the Pennsylvanian beds dip away from the fault at an angle of 15° and there is no anticline. No buried extension of the Criner Hills on the southeast has been found by wells.

Drilling has shown a buried fault in Sections 21 and 17, as previously stated, with a downthrow on the west of 350 feet in a distance of 450 feet in Section 21. No evidence of this fault is found at the surface in Section 21 or underground in Section 28 on a projection of the fault plane to the southeast. Moreover, the log of the well with shallow Ordovician limestone (penetrated for 130 feet) can be correlated with no fault in the Pennsylvanian. Wirt Franklin drilled twin wells west of the center of Section 17 of which the eastern had Ordovician at 1,795 feet and the western no Ordovician at 1,905 feet, where the hole was lost. The Magnolia dry hole, 1,000 feet west, found the limestone 1,340 feet deeper. The fault has been extended to pass between these wells as shown in Figure 4.

On the map of surface structure contours (Fig. 2) several cross-faults may be seen, each with a downthrow on the northwest. The maximum vertical displacement along the major faults is 250 feet. Innumerable small faults occur which cannot be shown except on a large-scale map, and many other faults probably exist in the area of no exposures. The major faults have their greatest displacement where there is the greatest bedding of the rocks (at the crest of the anticline), and most of the faults practically die out at a depth of about 900 feet. In these particulars they resemble the faults at Salt Creek, Wyoming.

At least two of the major faults are connected with cross-fractures in the Criner Hills. Near the center of Section 21 there is asphalt in the

[1] C. W. Tomlinson believes that these contacts on the northern edge of the Criner Hills are unconformities instead of faults, or else that the faulting occurred before Deese sedimentation (letter of October 19, 1926).

Ordovician limestones which must have come from the Pennsylvanian, but it is not along a fault. It is probable that at the time the block on

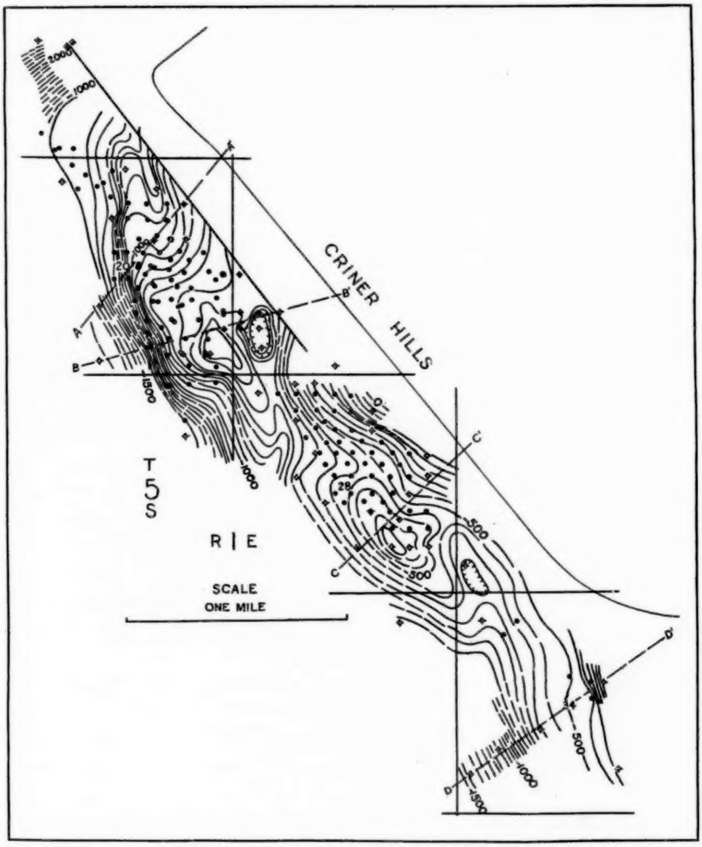


FIG. 4.—Structure contours of the Crinerville oil field on the eroded surface of the Ordovician, below sea-level, at a depth underground of 1,200–2,500 feet in the producing area. There is no hill on this eroded surface underlying the anticline at the surface of the ground. Oil was produced from the Ordovician in four wells surrounding the NE. cor., SE. ¼ of SE. ¼, Sec. 20. Contour interval, 50 feet. (Geology by Dollie Radler.)

the western side of the present Criner Hills sank, the cross-fractures in the Ordovician moved sufficiently to break the overlying Pennsylvanian.

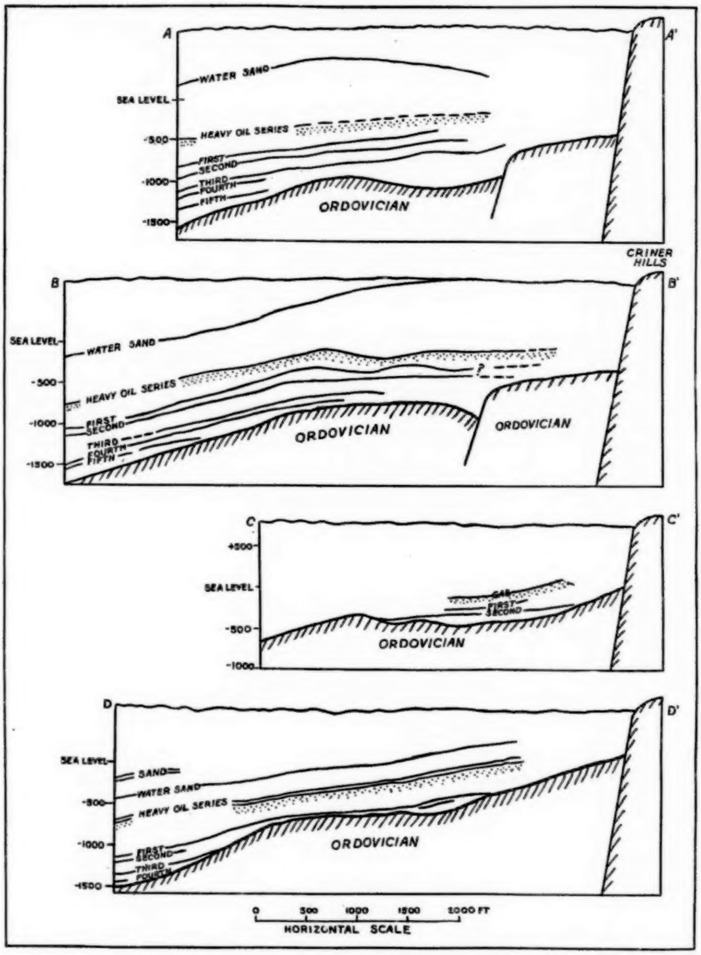


FIG. 5.—Cross-sections of the Crinerville oil field showing that the anticline disappears in the Pennsylvanian strata and that the eroded surface of the Ordovician is irregular. The subsidiary fault block west of the main Criner Hills fault was a topographic ridge during the deposition of the Pennsylvanian. Location of the sections shown on Figures 3 and 4. Length of section *A–A′*, one mile, and depth, 2,500 feet. Vertical scale in feet.

Well logs show that the minor faults do not affect the oil sands. There is a sharp syncline in the southwest corner of Section 21 beneath the surface fault, and several dry holes have been drilled here, but there is no fault between the three wells in the SW. $\frac{1}{4}$ of the SW. $\frac{1}{4}$ of Section 21, and there does not seem to be a fault north of the dry hole in Section 29.

A closed syncline on the oil sands marked by a dry hole in the NE. $\frac{1}{4}$ of Sec. 20, shown in Figure 3, underlies a surface fault and may be due to faulting. A northeast-southwest line of dry holes and small wells near the center of the N. $\frac{1}{2}$ of Sec. 20 coincides with another fault, and oil accumulation may be affected by it. The dry holes either miss the sand or find small showings of oil with salt water in contrast with good wells on either side.

Both the anticline and the minor faults disappear within 900 to 1,000 feet of the surface by flowage of the shale. It is clear that the anticline is not due to settling or compacting of the shales—one of the theories advanced to account for the anticlinal folds in northern Oklahoma. It was made by the same tangential compression which squeezed the Glenn sediments of the Ardmore basin into tightly folded long anticlines and synclines. Intensity of folding seems to increase upward, but this appearance may be due to buckling against the major fault plane. There are no drag dips in the Pennsylvanian at this fault, but instead there are steep dips toward the plane. The minor cross-faults may have been caused by this buckling.

## RESERVOIR ROCKS

The reservoir rocks, with the exception of the Ordovician limestone in four wells which produced from this horizon, are thin fine-grained sands which feather out or merge into brown shale where they intersect the unconformable surface of the older limestones. The productivity of wells has not been as great as in similar fields of southern Oklahoma, comparing sands of equal thickness. This may be due to shale content in them. There are no "shells" or cap rocks over the sands, and the change from shale to sand in cable-tool wells is frequently noticed only from cuttings. During Pennsylvanian sedimentation no sandstone was exposed in the Criner Hills, and the nearest source for quartz grains must have been many miles away; hence the oil sands probably represent material derived from the washing of sandy muds at or near sea-level in a shallow sea free from well-defined beaches and bars and entirely free from pebbles derived from the underlying limestone.

Volume of gas and water pressure are both low. The gas wells have yielded less than 5,000,000 cubic feet a day. Water has not been trouble-

some except in one well drilled into the Ordovician, from which a pocket of sulphur gas caused an artesian flow of sulphur water for several days.

Pennsylvanian shales are evidently the source rocks, and in this field, where the sands are more or less lenticular, it seems logical to assume the generation of oil locally.

RELATION OF ACCUMULATION TO STRUCTURE

Healdton, Hewitt, and Crinerville are all examples of buried Ordovician hills overlain by Pennsylvanian sands. Production has been found indigenous within the older rocks in the first two fields, and especially at Hewitt. The best production in each field comes from the Pennsylvanian quartz sands above the older quartz-free limestone. The buried hill has determined the location of the overlying anticline in each field, and the Pennsylvanian accumulation is anticlinal.

Crinerville is an excellent example of accumulation up the dip near the feather edge of sands. Similar conditions are described for some of the Ohio fields. The arrangement of oil, gas, and water within the sands accords with the structural theory of accumulation. Each of the five numbered sands, and, in Section 28, one intermediate sand, carries oil in a belt between its edge on the northeast and the water level on the southwest, but the belts are not directly superposed. The quantity of oil in each sand is probably determined largely by the richness in oil-forming material of the contiguous shale, and partly by the thickness and purity of the sand.

Development of the field has brought many surprises. It was first thought that the oil sands were anticlinal, and that production would be both east and west of the axis of the surface anticline; but the structure proved to be three terraces on a monocline, and the wells on the reverse dips in sections 20 and 21 found brown shale instead of sand. It was also thought that accumulation would be on the more gentle dips, but the reverse is true. Wells making 200 barrels offset small wells making 25 barrels, and the explanation appears to be sand condition rather than structure. Salt-water wells and some which missed the oil sands have been drilled along the supposed trace of subsurface cross-faults which are beneath the major surface faults. The small wells in Section 34, where the structure resembles that in Section 28, are explained by a thin and shaly sand. In brief, accumulation depends on the lensing-out of the sands and on the lithology of the sand bodies. Accumulation under similar structural conditions may be expected beneath any homocline where sands in a thick shale section are cut off by progressive overlap on an older eroded surface.

### OIL AND GAS

The oil is green by reflected light and amber color by transmitted light, and is similar to other Mid-Continent oil of the same grade. The average gravity in Section 20 is 34°; in Section 28, 39°; and in Section 34, 27.8°. The oil in the last two pools is darker in color than that of the same gravity in Section 20. The gravity of the oil in the fourth and fifth sands is 36°, and the color is lighter. The gravity of the oil in the Ordovician limestone was the same as in the Pennsylvanian sands. Differences in gravity of the oil in the three pools indicate no connection between the sands.

Oil is produced in two wells in Section 17 from the heavy oil series above the other sands, and the gravity of this black oil varies from 28° to 31°.

TABLE I

ANALYSES OF OIL, CRINERVILLE FIELD

| | Oil from "Second" Sand, Sammy Baptiste No. 1, SW.¼, NE.¼, SE.¼, Sec. 20 | Oil from Ordovician, Westheimer & Daube Fee No. 1 SW.¼, NW.¼, SW.¼, Sec. 21 |
|---|---|---|
| A. P. I. gravity at 60° F. | 33.2 | 30.7 |
| Saybolt viscosity at 100° F. | 58.8 | 66.0 |
| Percentage of sulphur | 0.72 | 0.83 |

FRACTIONAL DISTILLATION OF 800 CC. SAMPLE

| | Percentage | A.P.I. Gravity | Percentage | A.P.I. Gravity |
|---|---|---|---|---|
| Fraction up to 150° C. | 12.25 | 65.6 | 5.25 | 60.2 |
| Fraction 150°–200° C. | 11.70 | 53.7 | 11.50 | 51.6 |
| Fraction 200°–250° C. | 9.70 | 45.3 | 12.00 | 43.4 |
| Fraction 250°–300° C. | 11.12 | 38.8 | 11.75 | 38.0 |
| Residue and loss | 55.23 | ........ | 59.50 | ........ |

The casinghead gas carries 1½–2½ gallons of gasoline per thousand cubic feet of gas, and the volume of casinghead gas in Section 20 is approximately 1,000 cubic feet per barrel of oil, and only half this amount in Section 28.

Analyses of the oil are given in Table I. It is notable that the oil from the Ordovician was low in sulphur, although the accompanying gas was full of sulphur.

Gas has been found in three wells in Pennsylvanian sands and in one well in the Ordovician limestone. The maximum volume of the first wells did not exceed 3,000,000 cubic feet, but one Ordovician well (Marris No. 2) had a volume of 30,000,000 cubic feet of sulphur gas and caused an artesian flow of salt water of 15,000 barrels a day with about 200 barrels

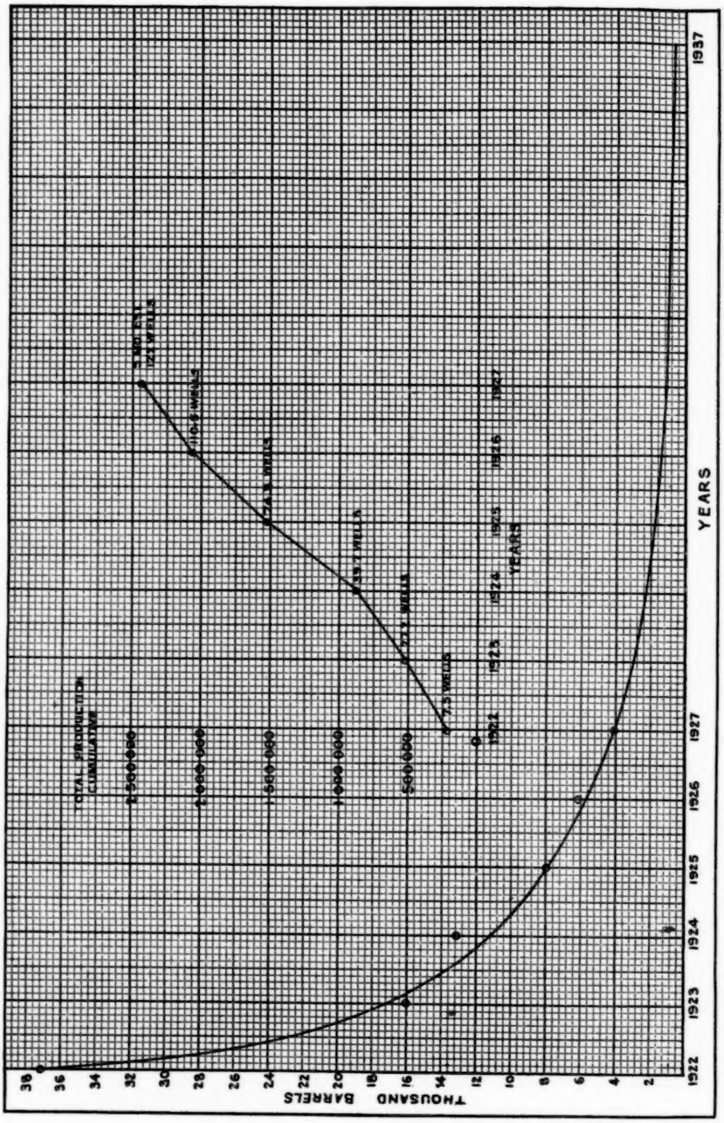


FIG. 6.—Decline curve for the Farve lease of 100 acres in Sec. 20 and cumulative total production curve for the Crinerville oil field. (By Earle S. Porter, for the Amerada.)

of oil. The rock pressure at Farve No. 9 in Section 20 was only 335 pounds at 1,486 feet, instead of a normal pressure of about 500 pounds.

### WATER

Water pressure is very low throughout the field, and this is one of the reasons for the small production. There is bottom water in Section 28, and several wells have been plugged back. Edge water has not encroached on the field. Water invariably produces 2–8 per cent of bottom sediment which is treated chemically and settled out.

Water pressure was high in the Ordovician limestone and flowed all the oil out of this limited reservoir. Two of the wells flowed 600 barrels of oil a day, but the producing horizon was so closely connected underground that each well affected the others and all went to water eventually, the highest well structurally being the last flooded. After water appeared in a well it increased very rapidly in quantity. Water and gas from the Ordovician have a strong sulphur odor.

Analyses of Ordovician water are given in Table II.

TABLE II

Analyses of Ordovician Water, Crinerville Field

| Constituent | Marris No. 2, SE. Cor. Sec. 20 | S. Baptiste No. 4, NE., SE., SE., Sec. 20 |
|---|---|---|
| | Grams per Liter | Grams per Liter |
| Calcium chloride | 25.380 | 23.510 |
| Sodium chloride | 89.700 | 85.150 |
| Magnesium chloride | 11.818 | 11.690 |
| Iron and aluminum oxides | 0.110 | 0.120 |
| Silicic acid | 0.050 | 0.090 |

### OIL AND GAS PRODUCTION

All of the wells are drilled with standard tools, and the average time of drilling 1,000 feet is 3 weeks. The spacing is 4 acres to the well.

A decline curve for the Farve lease in Section 20 (Fig. 6) is an average for the field. The productive life of the field will probably be at least 20 years. The maximum production per acre will be 10,000 barrels for the 100 acres of the Farve lease, and 7,000 barrels for the Sammy Baptiste lease south of it. Owing to the fact that there is only one good oil sand in Section 28, the production there will be only 5,000 barrels per acre.

The total ultimate yield of the field will be about 3,300,000 barrels from 560 acres, or 5,900 barrels per acre.

# THE MORRISON FIELD, PAWNEE COUNTY, OKLAHOMA[1]

EVERETT CARPENTER
Bartlesville, Oklahoma

## ABSTRACT

The Morrison field of Pawnee County, Oklahoma, is southeast of, and closely related to, the Kay County district in structure and producing horizons. Surface anticlinal structure is readily mapped on the Fort Riley limestone of Permian age. Subsurface structure is generally similar to the surface, and is mapped on the Tonkawa sand, Layton sand, and "Mississippi lime" of Pennsylvanian age, and the "Wilcox" sand of pre-Pennsylvanian. The amount of closure increases with depth, amounting to about 150 feet on the "Wilcox" sand. Depth of producing sands ranges from about 2,000 to 3,800 feet. The total production of the field by the end of 1926 was 4,566,800 barrels of oil, or more than 11,000 barrels per acre.

### LOCATION

The Morrison field is located in T. 22 and 23 N., R. 3 E., Pawnee County, Oklahoma. It lies southeast of the Kay County district, with which it is closely related as regards structure and producing horizons. It has a producing area of only about 320 acres, but has produced 4,566,800 barrels of oil at the close of 1926.

### HISTORY

The history of the Morrison field commences with the year 1915. The structure was discovered in January of that year by Frank Buttram, who was then employed by the Fortuna Oil Company. The first well, George L. Miller No. 1, was completed by Robert Watchorn on December 27, 1915, as a 35,000,000-cubic foot gas well in the Tonkawa sand. During the interval between 1915 and 1922 the development was confined to the gas sands found between 2,000 and 2,500 feet, but on July 14, 1922, George L. Miller No. 3 was completed as an oil well in the Layton sand, found at 2,752 feet. This well was deepened to the "Wilcox" sand in October, 1923, and had an initial production of 650 barrels.

### STRATIGRAPHY

The rocks exposed at the surface in the Morrison field are of Permian age. They consist mostly of red shale and sandstone, but two limestones

[1] Presented by title before the Association at the Tulsa meeting, March 26, 1927. Manuscript received by the editor July 30, 1927.

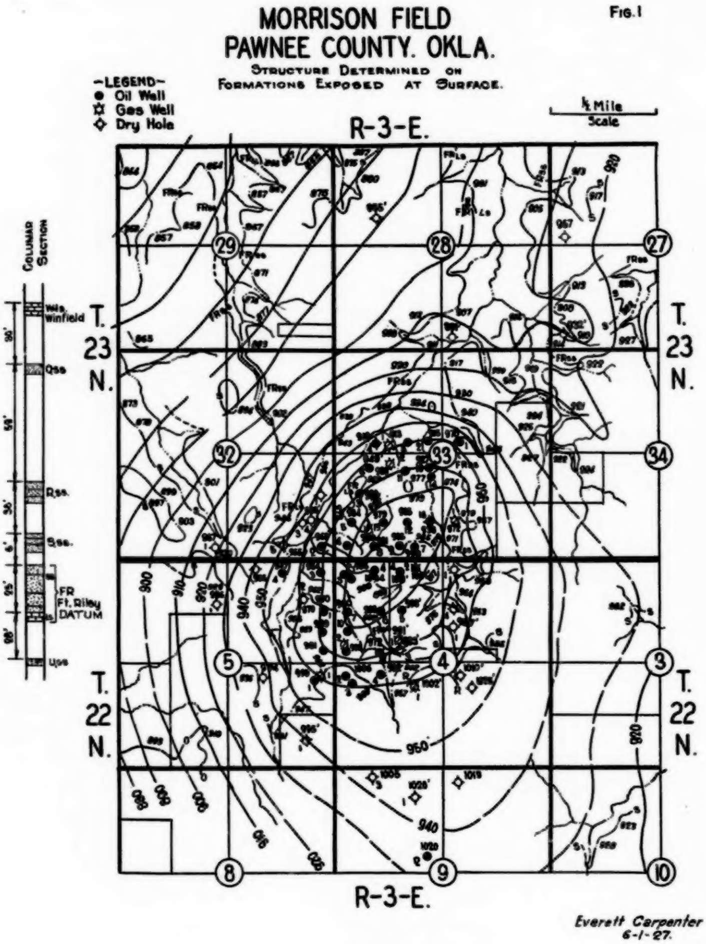


FIG. 1.—Geologic structure of the surface formations, Morrison field. Contours above sea-level. Contour interval, 10 feet.

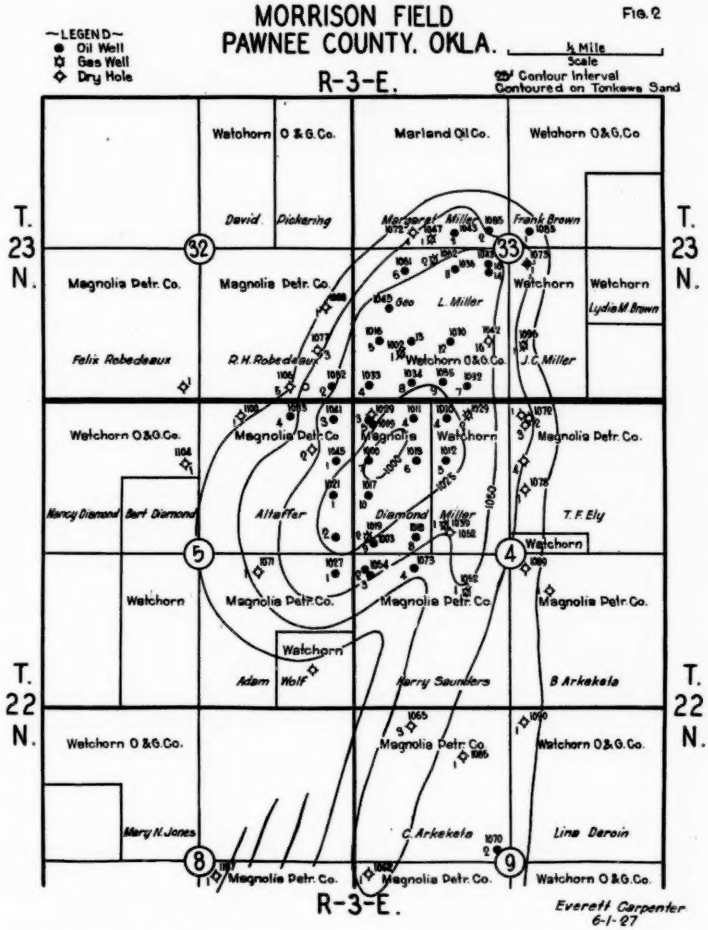


FIG. 2.—Geologic structure contoured on the Tonkawa sand in feet below sea-level, Morrison field.

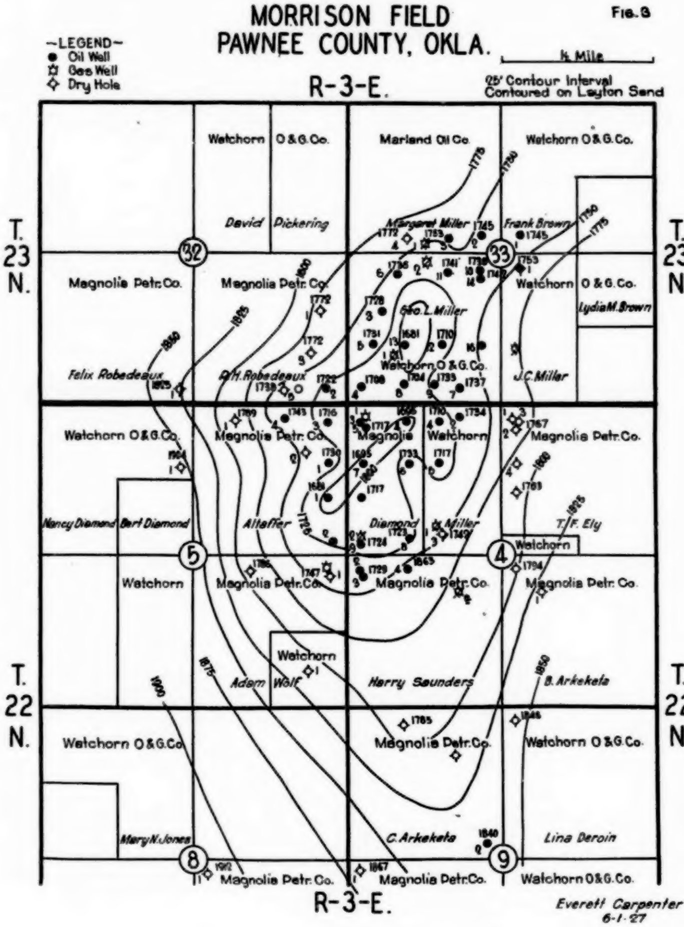


FIG. 3.—Geologic structure contoured on the Layton sand in feet below sea-level, Morrison field.

are present. The Fort Riley limestone outcrops in the field and is the datum used in mapping the structure. This formation has lost the calcareous nature it possesses in Kansas and northern Oklahoma, and consists mostly of sand, with a limestone bed about 10 feet thick at its base. The Winfield limestone outcrops west of the field about 160 feet stratigraphically above the Fort Riley. The interval between the two consists of red sand and shale.

### SUBSURFACE STRATIGRAPHY

Subsurface correlations in the Morrison field are comparatively difficult, due to the lack of persistent key beds. The Foraker limestone is found 500 feet below the Fort Riley, but it is not easily recognized. The first dependable correlation to be made is on the Tonkawa sand found at a depth of 2,000 feet. The section between the Tonkawa sand and the Layton sand, found at 2,700 feet, is irregular, and no accurate correlation is possible throughout wide areas. The Layton sand can be correlated in most of the area, and also the Kansas City–Oswego group. The "Mississippi lime" found on the structure at a depth of 3,800 feet below the Fort Riley is always distinguishable; but on account of its variable thickness the depth of the "Wilcox" cannot be definitely forecast.

### STRUCTURE

The structure as revealed by the surface rocks is a typical anticline (Fig. 1). It has a north-south length of about one mile and a productive width of about ½ mile (Fig. 1). The fold is characterized by a reverse dip of about 40 feet, although probably not all of the east flank is exposed. The south end of the structure is not clearly revealed, due to the lack of exposures of any key horizons.

Several horizons may be used for subsurface mapping with essentially similar results. For the purpose of this study four horizons were used, namely, Tonkawa, Layton, "Mississippi lime," and "Wilcox" sand (Figs. 2, 3, 4, and 5). These formations, except the "Mississippi lime," contain oil or gas, and measurements to them are probably more accurate than others. The structure as revealed by subsurface rocks is similar in outline to that determined by surface exposures. In general the amount of closure increases with depth to the top of the "Wilcox" sand, where there is a closure of about 150 feet.

### PRODUCTION

The production obtained from the Pennsylvanian strata is mostly gas, although oil has been found in commercial quantities in the Layton sand

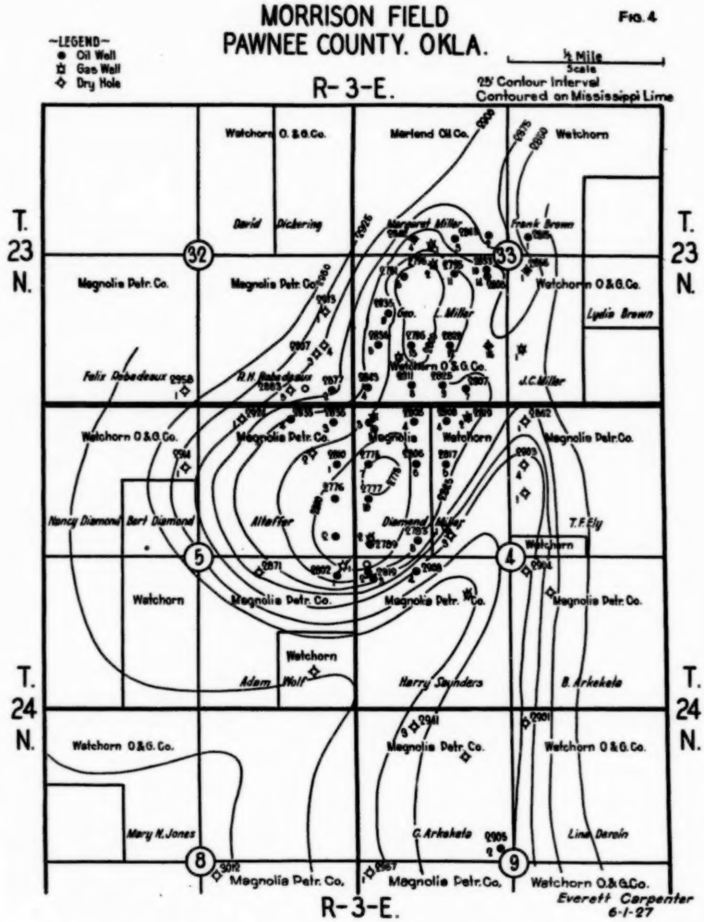


FIG. 4.—Geologic structure contoured on the "Mississippi lime" in feet below sea-level, Morrison field.

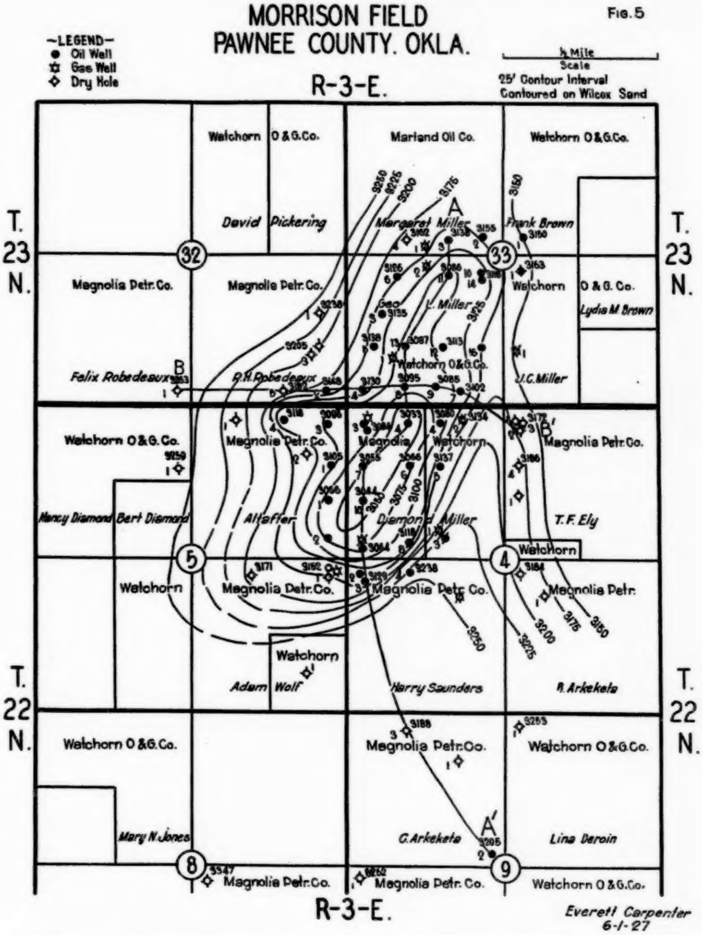


FIG. 5.—Geologic structure contoured on the "Wilcox" sand in feet below sea-level, Morrison field. Shows location of cross-sections $AA'$ and $BB'$ (Figs. 6 and 7).

in several wells at a depth of about 2,700 feet. The producing sands are the Tonkawa gas sand at 2,000 feet, two unnamed gas sands at about

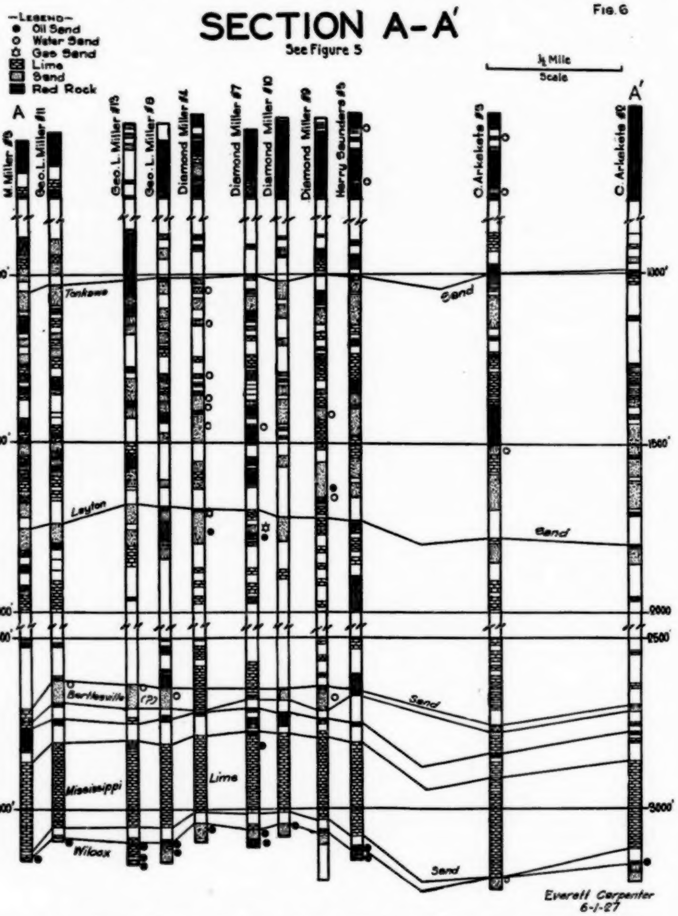


FIG. 6.—Geologic cross-section *AA'* as shown by well logs. For location in field, see Figure 5. Depths shown in feet.

2,300 and 2,500 feet, and the Layton oil sand at 2,700 feet. The Bartlesville sand is probably present on the Morrison anticline, but it is un-

productive. Some slight showings were obtained in the upper part of the "Mississippi lime," but they were not sufficient to be commercial.

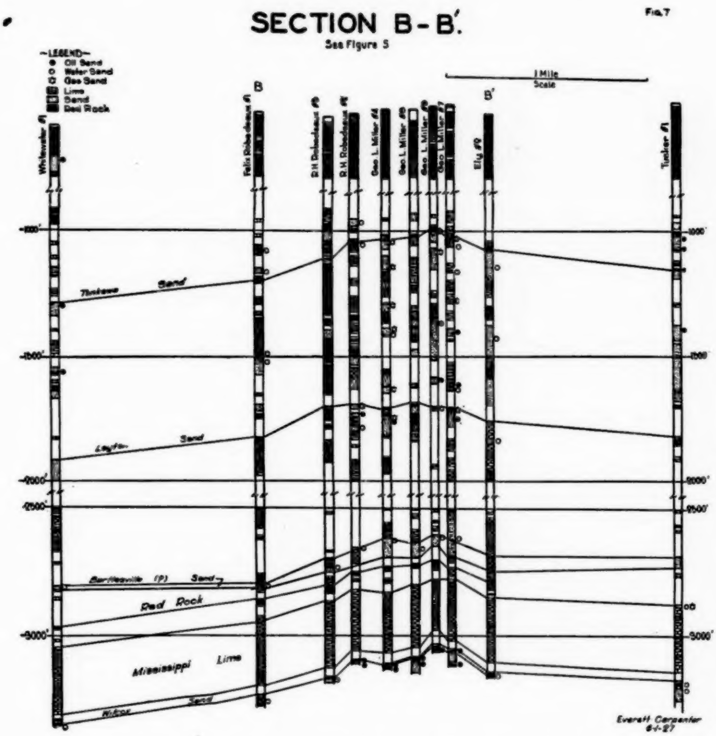


FIG. 7.—Geologic cross-section *BB'* as shown by well logs. For location in field, see Figure 5. Depths shown in feet.

The production obtained from the pre-Pennsylvanian strata is all from the "Wilcox." It is the best oil-producing formation, and has furnished more than 90 per cent of the oil in the field. It seems that all the oil-bearing horizons have been tested, but several showings in the siliceous lime have been reported in wells drilled off the structure. It is possible that when a deeper well is completed on the top of the dome, additional production may be obtained.

The following production data are from the office of the Corporation Commission and are thought to be accurate:

PRODUCTION OF THE MORRISON FIELD

| Year | Barrels |
|---|---|
| 1922 | 42,318 |
| 1923 | 97,576 |
| 1924 | 1,253,080 |
| 1925 | 2,232,996 |
| 1926 | 940,830 |
| Total | 4,566,800 |

At the close of 1926, the average yield for the field was more than 11,000 barrels per acre. The production during the remainder of the life of the field should be almost 15,000 barrels per acre.

# THE SEMINOLE UPLIFT, OKLAHOMA[1]

SIDNEY POWERS
Tulsa, Oklahoma

## ABSTRACT

A brief description of the Seminole uplift on which the Seminole oil fields are located written one year after the discovery is given in advance of complete knowledge of the geology. This preliminary statement attempts to present a picture of the geology of the uplift together with production statistics to show the remarkable reservoir conditions in the "Wilcox" sand and the enormous quantity of oil concentrated in a limited area. The effect of the air lift, which has been in large part responsible for maintaining the production, is not discussed. Reference to other publications and discussion of other possible interpretations of structural conditions are omitted for the sake of brevity.

## HISTORY

The Seminole uplift, on which the Seminole, Searight, Earlsboro, Bowlegs, Little River, and other oil fields have been developed, is a pronounced structural feature north of the Arbuckle Mountains (Fig.1) discovered by wildcat drilling on surface folds of anticlinal type in an area which was not considered favorable for oil accumulation because of the supposed absence of underground structure and of producing sands.

Early in 1926 the oil fields farthest to the southwest were Wewoka and Cromwell. Cromwell, producing from the Cromwell sand of Mississippian age, indicated possibilities of additional pools in sand lenses of the same age, but none had been found. Wewoka, discovered by accident, had produced from several lenticular sands of Pennsylvanian and Mississippian ages but of uncertain correlation. "Wilcox" sand, of Ordovician age, was discovered on a random location at the edge of the Wewoka shallow-sand field by the Magnolia Petroleum Company on December 18, 1925, at a depth of 4,096 feet. This well made 4,000 barrels a day. An extensive drilling campaign for "Wilcox" production resulted in a field ultimately comprising more than 600 acres.

Prior to the discovery of the Wewoka deep producing sand, the large "Wilcox" sand fields (and "Siliceous lime" where the "Wilcox" is eroded away) were Tonkawa, Depew, Stroud, and Garber. The others com-

[1] Published by permission of the Amerada Petroleum Corporation, Tulsa, Oklahoma. The writer is greatly indebted to Jess Vernon, who has prepared subsurface maps of the district, and to Miss Dollie Radler of the Amerada for the data contained in this paper.

prise 80 acres or less. Wewoka produced wells flowing 4,000 to 7,000 barrels a day, but the field is "spotted" and underlies only part of the shallow field.

Discovery of shallow-sand production at a depth of 3,558 feet at Earlsboro by Morgan and Flynn in December, 1925 (Fig. 2), did not excite the producers, because the well made only 70 barrels. The Earlsboro sand (post-Gilcrease) is in the Pennsylvanian. A year later the deep Earlsboro field was discovered near by.

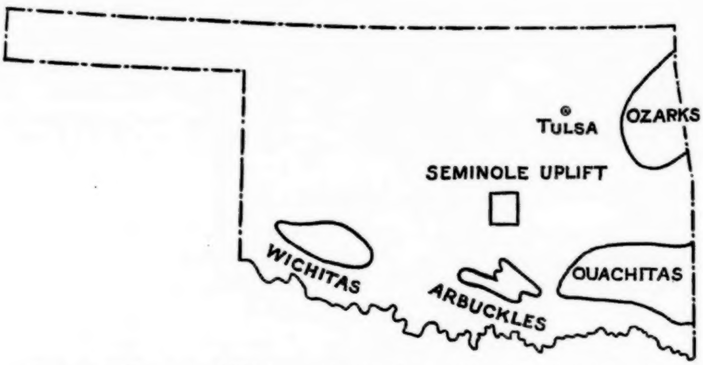


FIG. 1.—Outline map of Oklahoma, showing the location of the Seminole uplift

Many dry holes and a few shallow-sand producers had been drilled north of the Arbuckle Mountains and south of Canadian River, but the Ordovician had everywhere yielded sulphur water.

Seminole was discovered by the Indian Territory Illuminating Oil Company on March 7, 1926. Their well, in the NW. cor., SE. $\frac{1}{4}$, Sec. 24, T. 9 N., R. 6 E., flowed 1,100 barrels a day from the Hunton lime of Silurian age at 4,012 feet. Hunton production was not considered valuable, because only one field (Skellyville in T. 15. N., R. 6 E.) has yielded profitable production from this horizon.

The "Wilcox" sand was discovered by the Amerada Petroleum Corporation in a well one-fourth mile east of the Indian Territory discovery on July 6, 1926. This well made only 60 barrels a day.

At the same time R. F. Garland and the Independent Oil Company were drilling a well in the SW. cor., NE. $\frac{1}{4}$, Sec. 26, same township. Only 4 feet of Hunton limestone was found. The underlying Sylvan shale was identified by Roy C. Quiett, geologist for the Indian Territory Illuminat-

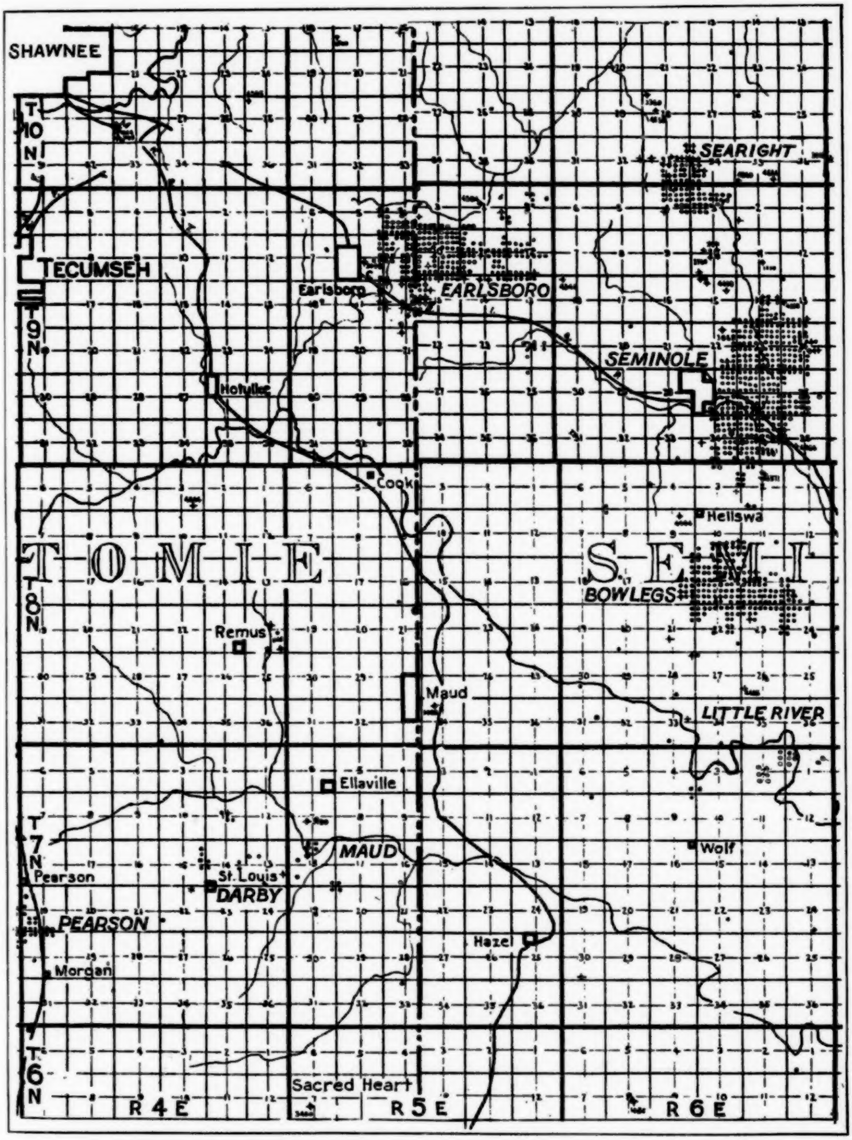


FIG. 2.—Map of the Seminole uplift, showing the oil fields as of August, 1927. The limit of the plateau probably falls within the boundary of this map, but cannot be defined more closely at the present time. Width of map, 18 miles.

ing Oil Company, by means of a graptolite; and the well was found to be structurally higher than those previously drilled.

The Garland-Independent well came in, July 16, flowing 1,500 barrels a day from a depth of 4,069 feet, and later made as much as 8,000 barrels a day, after the well was deepened. During 1926 it produced 650,000 barrels.

Other discoveries followed. Hunton oil was found by F. J. Searight in the NE. ¼, SE. ¼, Sec. 33, T. 10 N., R. 6. E, opening the Searight field, and the "Wilcox" sand was found by him on October 11 in one of the Hunton wells drilled deeper. "Wilcox" production was found on November 8 at Earlsboro by the Gypsy-Amerada-Westland in the NE. cor., Sec. 16, T. 9 N., R. 5 E. Bowlegs was discovered by the Indian Territory Illuminating Oil Company, in Sec. 13, T. 8 N., R. 6. E, December 23, and also by them in Sec. 15, same township, a week later. Little River in Sec. 1, T. 7 N., R. 6 E., was discovered by them in July, 1927. The depth of the "Wilcox" sand in all these fields ranges from 3,950 to 4,450 feet only.

Hunton oil has been produced south of Maud for many years and two new pools, in T. 7 N., R. 4 E., one the Darby field at St. Louis and one at Pearson, have been developed. Salt water has been found in the "Wilcox" sand under both fields.

## STRATIGRAPHY

Formations of upper Pennsylvanian age crop out in Seminole and Pottawatomie counties. They consist of shale, sandstone, conglomerate, and limestone, in decreasing order of abundance.

Underground, the Pennsylvanian extends to a depth of about 3,700 feet and the lowest formation is the Boggy, which is a considerable distance above the base of the Pennsylvanian in normal sequence. The thickness of the entire section across the uplift differs in the different local folds. Individual formations are not distinguished above 3,700 feet, because wells are drilled with rotary tools and samples are seldom saved.

The Mississippian consists of the Mayes formation above, 80 to 130 feet thick, underlain by the Woodford formation 50 to 150 feet thick (thickening to more than 200 feet in T. 7 N.). In synclines, Fayetteville shales are present above the Mayes. The Mayes is of Chester age.

Hunton limestone (Siluro-Devonian), probably the Chimneyhill limestone member, of Silurian age, is present locally over the uplift both on anticlines and synclines, but is absent on the large anticlines and in

some synclines. The maximum thickness is about 350 feet on the St. Louis anticline, which seems to be a buried hill on top of the Hunton because the Hunton thins to the north and south and because the "Wilcox" sand carried salt water under the discovery well in the Hunton. Oil has been found in the Hunton in the vicinity of the original Seminole and Searight discovery wells and also in the Pearson and Darby (Maud) areas. The Hunton is 30 to 90 feet thick where the original discovery wells were drilled. In many places where the Hunton is absent, the Misener sand is found at the unconformity and a few wells have produced oil from this sand.

The Ordovician consists of 60 to 100 feet of Sylvan shale underlain by about the same thickness of Viola limestone, which in turn is underlain by an unknown thickness of Simpson formation. Sands in the Simpson are called "First" and "Second Wilcox," or "post-Wilcox" and "Wilcox." Above and between these sands there is in most places dolomite, but there is no dolomite below the "Second" or "True Wilcox." Where dolomite is present above the first oil sand, the dolomite is 15 to 60 feet thick. The pay sands are 20 to 80 feet thick. The second sand is underlain by green shale equivalent to the Tyner formation of the Ozarks. Dry holes have penetrated sand bodies more than 600 feet thick at Wewoka and Seminole which give possibility of deeper production. Correlation of the Simpson sands is based on lithology. Some wells at Earlsboro and Bowlegs have important increases in production when deepened into the "second pay." Deepening of wells at Seminole has not proved profitable.

In the Arbuckle Mountains a well which started in the Viola limestone penetrated 2,730 feet of Simpson above the Arbuckle limestone. The Arbuckle may be several thousand feet thick at Seminole, just as in the Arbuckles, but the thickness may not be determined for many years.

## STRUCTURE

### SURFACE FOLDS

North of the Arbuckle Mountains and west of the Ozarks, the Prairie Plains homocline, which drops west at a rate of 30 to 100 feet to the mile, is interrupted locally by folds of the Plains type—noses and low anticlines and anticlinal buried hills.

In the vicinity of the Seminole uplift the dip is about 90 feet to the mile west. The only pronounced structural feature at the surface near Seminole is a line of echelon faults and several prominent noses, such as shown in Figure 3, both extending through Range 6. There are no faults either east or west. Noses in Range 7 are very uncommon and insignifi-

cant; and those west of Range 6 are gentle, with a few conspicuous and widely scattered exceptions. The concentration of structural disturbances in Range 6 was interpreted by several geologists in 1924 and 1925 as indicating a line of folding from the Arbuckles to the buried hills of the Cush-

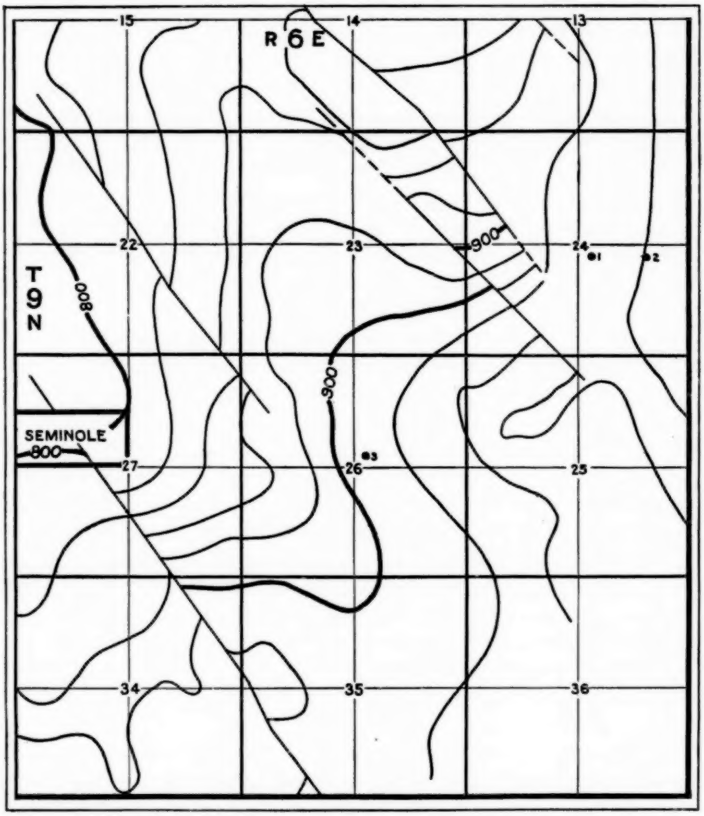


FIG. 3.—Surface-structure contour map of the Seminole City oil field made by Charles W. Roop for the Indian Territory Illuminating Oil Company. The discovered wells are: No. 1, Indian Territory; No. 2, Amerada; No. 3, Garland-Independent. The normal dip is west and is interrupted by several *échelon* faults. There is a pronounced anticlinal nose in the S. ½ of the SW. ¼ of Sec. 23 and syncline in the SW. ¼ of Sec. 26 and faulted anticline in W. ½, Sec. 35. Contours above sea-level with a contour interval of 20 feet. Width of map, 3 miles.

ing field. A similar line of folding between the Arbuckles and Ozarks was proved by the development of Wewoka. The Indian Territory Illuminating Oil Company was the first to concentrate purchases of acreage in Range 6 on this conception of structure.

Seven of the discovery oil wells on the Seminole uplift have been drilled on surface folds (four were drilled by the Indian Territory). An equal or greater number of noses have been tested dry. Surface noses may overlie anticlines or synclines, as in the Seminole field (Figs. 3 and 4), or sand lenses in the Pennsylvanian or buried hills on the Hunton. The anticlinal type of fold is readily explained except above synclines, and the conspicuous example at Seminole may have been influenced by buried topography.

Nothing is known about the persistence with depth of surface folds in the Pennsylvanian, but it is known that the faults disappear downward and are the effect of torsional movement in the most brittle part of the Pennsylvanian section. Casing is set in the rotary wells near the base of the Pennsylvanian, and the older rocks are studied from samples.

### SMALL FOLDS

All the pre-Pennsylvanian rocks are closely folded into minute folds which might be called "puckers" (Fig. 4). Those at Seminole (Fig. 4) are typical. Wells are drilled 330 feet from property lines, or 660 feet apart. The deepest of such folds is in Bowlegs where one well is 700 feet lower structurally than the offset wells. Considered as a whole, these anticlinal folds have accordant tops, and the synclinal folds fairly accordant bottoms. Smooth cross-sections across the former would show broad anticlines such as encompass oil fields, but cross-sections across the latter would not all show these anticlines. The amount of their structural relief ranges from 100 to 300 feet, as a rule, and that from the summit of an oil field to the bottom of an adjacent syncline, 500 to 700 feet.

These folds are characteristic of Range 6. They are less numerous at Earlsboro and are not noticed at Pearson and Darby (Maud) in the Hunton, but this may be because of erosion on top of the Hunton. They are probably equally numerous in the synclines and anticlines in Range 6.

### LARGE FOLDS

Sections over broad areas show, as just stated, that there are low anticlines and synclines which comprise the Seminole uplift. A contour on the top of the Viola limestone 3,250 feet below sea-level would approximately outline the uplift and demark the fields. The highest point

on the same datum is about 2,950 feet; and the lowest production, 3,450 feet (except in the local synclinal folds, all of which produce oil even at 3,630 feet). The size of these larger features is to be judged by the size of

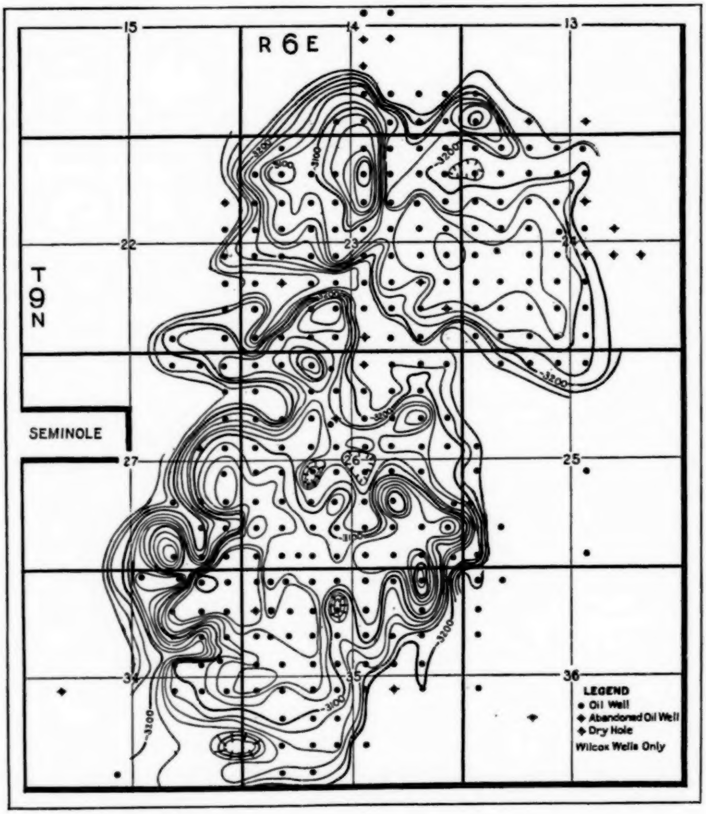


FIG. 4.—Subsurface contour map of Seminole City oil field made by Jess Vernon for the Amerada Petroleum Corporation. The contours on the edges of the field are omitted because of inadequate information. The syncline in the NE. ¼ of Sec. 26 underlies the surface nose, and the anticline in the SW. ¼ of Sec. 26 underlies the surface syncline. The broad anticline which controls production is interrupted by many small folds. Contours are on top of Viola limestone below sea-level and contour interval is the same as in Figure 3.

the oil fields. Their location and extent cannot be judged from surface geology.

ORIGIN

All of the formations at Seminole should thicken toward the Arbuckle Mountains, one of the sources of supply for the sediments; uniformity of total thickness from south to north therefore indicates structural disturbance. There was erosion after the Simpson sands were deposited and before the Viola was laid down. Regional uplift and folding, which produced the Seminole uplift and the large, low folds upon it, came after Hunton deposition. The Hunton was removed from part of this area of low topographic relief, but erosion did not remove the underlying Sylvan shale (averaging 90 feet in thickness) from any spot thus far found. Some of the drainage channels were in anticlines, some on synclines.

Folding of the uplift (in two directions?) followed Mississippian sedimentation and developed the small folds. Folds in the Mayes and Simpson are superposed and parallel. Faulting will not account for the small folds because they are too small, too irregular, and characteristically more or less circular. Repetition of section has been found by careful microscopic study of cuttings in only one well. Such folds have not been found elsewhere in the Mid-Continent fields, but minutely compressed folds which resemble them are plentiful in the Arbuckle Mountains. The drill has proved their existence. The geology of the pre-Pennsylvanian rocks in the Seminole uplift is known far better than the geology of the Arbuckle Mountains where the rocks are exposed in pristine grandeur.

After erosion of the uplift in early Pennsylvanian time, shales of Boggy age were deposited over it. During the time of this sedimentation the uplift was evidently higher on the west than on the east because post-Pennsylvanian westward tilting has produced a dip of about 90 feet to the mile toward the west. Pennsylvanian sediments thin westward and northward and conglomerates on the east and south merge into sandstones underground farther west.

The character of the Pennsylvanian sediments indicates that there were irregular uplifts of the Arbuckle and Ouachita mountains and these movements must have caused tilting and even folding over the Seminole uplift. Pennsylvanian sediments throughout Oklahoma seem to have been gently re-folded over anticlines and buried hills during, as well as after, sedimentation.

OIL ACCUMULATION

Hunton limestone may be considered in a broad way as eroded from the uplift except around the edges and the southwest part. Oil is confined

to buried hills and is probably trapped in the porous upper surface into which it has migrated from the adjacent Mississippian shales.

"Wilcox" oil occurs at the top of the Simpson sands under the Viola limestone, which is characteristically free from microscopic fossils. The oil sands are underlain by green shales, correlated with the Tyner shales of the Ozarks, which are probably the source of the oil.

The large oil fields cover large anticlines. Production is obtained from the entire fold, both on anticlinal and synclinal puckers, many of the latter being lower structurally than the water level of the field. This condition proves that accumulation took place before the local folds were developed and, hence, at the time of post-Hunton folding. The water level of all the fields is approximately the same, and the salt water does not have a sulphur odor (except at Wewoka). Regional southward tilting of the uplift after accumulation is indicated by the higher water level on the north side of the fields.

## OIL PRODUCTION

Two outstanding characteristics of the Seminole fields are the enormous productivity of the "Wilcox" sand and the extent and close spacing of the fields. Elsewhere in Oklahoma there may be one or even several anticlinal fields in a township, each comprising an area of a square mile or less, wide spacing being roughly proportional to large size. Developments during one year on the Seminole uplift indicate the possibility of a field covering from 1 to 5 square miles with a spacing of at least one field for each township. Cushing is the only larger anticlinal type of field. Glenn pool, Bird Creek, and the other shallow fields are broad sand lenses.

One year after the Garland-Independent well struck the "Wilcox" sand the uplift had produced 74,874,235 barrels (to July 21, 1927) with a value of $146,000,000 from 586 wells. The total production of individual fields is shown in Table I.[1]

Of this total the Earlsboro sand had produced 3,490 barrels from 25 wells; the Hunton, 8,600 barrels from 58 wells; and the "Wilcox," 483,197 barrels from 528 wells.

The amounts of oil recovered by the five leading operating companies on that date are shown in Table II.

On July 22, 1927, there were 532 locations and drilling wells on the Seminole uplift. The production per acre for the Seminole City field was already nearly 14,000 barrels, with an estimated total ultimate yield of

[1] Statistics from *Oil and Gas Journal*, July 28, 1927; *Tulsa Tribune*, July 17, 1927.

20,000 barrels. The maximum yield for 40 acres was more than 30,000 barrels per acre, indicating an ultimate yield of 50,000 barrels for the best leases.

The largest individual wells ever completed were at Earlsboro and Little River, each making more than 13,000 barrels a day. The maximum daily production to August 12, when the shutdown agreement took effect, was 527,400 barrels on July 30, from 637 wells.

TABLE I

SEMINOLE UPLIFT PRODUCTION FOR FIRST YEAR

| | Barrels | Wells | Acres (Approx.) | Daily Production in Barrels, July 22 |
|---|---|---|---|---|
| Seminole | 43,305,028 | 305 | 3,050 | 90,160 |
| Bowlegs | 14,650,688 | 163 | 1,630 | 201,909 |
| Earlsboro | 8,637,760 | 101 | 1,010 | 170,873 |
| Searight | 8,220,759 | 42 | 420 | 32,345 |
| Total | 74,874,235 | 611 | 6,110 | 495,287 |

TABLE II

SEMINOLE UPLIFT PRODUCTION BY PRINCIPAL COMPANIES, FIRST YEAR

| | Barrels | Wells | Acres (Approx.) |
|---|---|---|---|
| Carter Oil Co. | 12,690,682 | 86 | 860 |
| Indian Terr. Illum. Oil Co. | 7,974,168 | 76 | 760 |
| Gypsy Oil Co. | 6,084,689 | 51 | 510 |
| Amerada Petroleum Corp. | 5,555,159 | 28 | 280 |
| Pure Oil Co. | 5,473,508 | 38 | 380 |

The price of Seminole was \$2.63 per barrel for the first 4½ months, \$1.87 for the next 4 months, \$1.61 for the next two weeks, and subsequently has been approximately \$1.34. The operators have already received approximately \$146,000,000 and have spent \$60,000,000 for development exclusive of leasehold costs.

## SUMMARY

The Seminole uplift is a large structural feature comparable in size to one of the units which comprise the Arbuckle Mountains. It was formed by gentle upwarp in late Devonian time, and the broad anticlines and synclines were compressed after the close of the Mississippian period

into small folds, many of which are only 1,500 feet wide and have several hundred feet of structural relief. They are essentially synclinal depressions. During and after Pennsylvanian sedimentation, warping and gentle folding took place. Noses at the surface reflect anticlines in the older strata or sand lenses in the Pennsylvanian or buried hills on the Hunton lime.

Enormous quantities of oil have accumulated in relatively thin sands, 20 to 80 feet thick, yielding a maximum ultimate production of 50,000 barrels per acre. The Ordovician is the greatest oil reservoir rock in Oklahoma and has supplied the gushers of Cushing, Billings, Ponca, Tonkawa, Garber, Depew, Stroud, Wewoka, and at least 50 smaller fields as well as the fields on the Seminole uplift. Of all these fields Cushing may ultimately prove to be the best because it is the largest, but the Seminole fields combined have had a higher daily average production than Cushing.

Oklahoma—the Prairie Plains homocline—has been found to be underlain by remarkable structural features whose existence is not reflected at the surface. Without these buried hills, ridges, and uplifts the story of oil in the state would have been practically closed in 1912 with Glenn pool, the last of the great sand lens fields. Geological work commenced in Oklahoma in 1913, attained a high state of perfection by 1925, and was supplemented by geophysical work at that time. Few geologists suspected a buried ridge under Range 6, and not one a Seminole uplift, the largest structural feature yet revealed by the drill.

Vast areas of Prairie Plains await the drill and more buried hills entice the speculative geologist.

# GEOLOGICAL NOTES

## BURIED RIDGES IN WEST TEXAS[1]

### RÉSUMÉ

The importance of West Texas and especially of a salt, gypsum, and anhydrite basin as one of the great oil-producing areas of the Mid-Continent region is now obvious. So little has been written regarding this oil accumulation that a brief explanation of the type of accumulation, which is like that of Mexico and Persia, is given, even though detailed maps and sections are still confidential.

### GEOGRAPHY

From the viewpoint of a geologist, West Texas is the area south of the Panhandle and west of the central Texas oil fields. More particularly, it is the area underlain by the south half of the Permian salt basin. For the sake of brevity, discussion in this paper is limited to the part of the basin near Pecos River, from Big Lake on the east to Yates on the west and south and the southeastern corner of New Mexico on the north (Fig. 1).

Geographically the Pecos valley is bounded on the west by the Trans-Pecos region (which is mountainous west of Fort Stockton), on the northeast by the Llano Estacado, or Staked Plains, and on the southeast by the Edwards Plateau. Buttes from the Edwards Plateau encroach on the Llano Estacado in the vicinity of the McCamey field.

### HISTORY

In November, 1919, the first gas well was drilled in the Permian basin of Texas, north of Amarillo, in an area condemned by the leading petroleum geologists of the day because of the lithology of the known sediments —red beds, salt, gypsum, anhydrite, and dolomite—and because of their supposed enormous thickness, far too great for the limit of profitable drilling at that time, about 3,000 feet. Charles N. Gould overcame these superstitions, located the discovery gas well (depth 1,670 feet) and opened a new territory of which neither he nor anyone else appreciated the possibilities at that time. The following year some of the gas wells were drilled into arkose and granite, and in 1921 the Humble and Gulf proved that the

[1] Published by permission of the Amerada Petroleum Corporation, Tulsa, Oklahoma.

salt basin concealed at least one buried granite ridge, the Amarillo Mountains, which are the westward extension of the Wichita Mountains.

In 1919, prior to the Amarillo discovery, there were a few shallow wells near Fort Stockton on the west side of the Permian basin which produced a few barrels of heavy oil smelling strongly of sulphur. Some wells north of Toyah and also near Dixieland on Pecos River had made brief flows

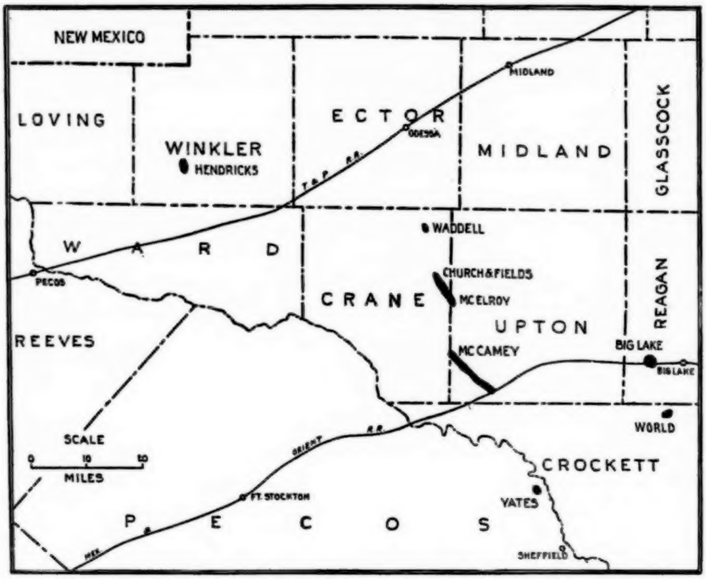


FIG. 1.—Map of west Texas showing location of the oil fields on the west side of the Permian salt basin.

of similar oil. A few showings of oil had been found in shallow wells in Howard County, on the east side of the basin. This oil had come from porous limestone or thin sand lenses, and nothing was known about the structure of the areas either at the surface (because of unconformities and lack of exposures) or underground.

In May, 1923, the Big Lake field was discovered by random drilling and developed slowly by two companies into a major field which will have an ultimate yield of more than 25,000 barrels per acre. Geological work, commenced at this time, led to the discovery of the other fields farther west. The Westbrook field in Mitchell County, on the east side of the

basin, was discovered the same year by random drilling.[1] The later history of development of the east side of the basin is omitted.

The only field near Big Lake is the World pool, discovered in 1925.

Drilling on geologic advice led to the discovery of the Artesia field, New Mexico, in 1924, and to the discovery of Maljamar, east of Artesia, in 1926.

Wildcatting in West Texas was very disappointing until October, 1925, when the Republic Production Company drilled the discovery well of the McCamey field on the geological recommendation of the Marland Oil Company. At this time the Gulf Refining Company, acting on the advice of Ben C. Belt, had taken extensive blocks of acreage upon which the McElroy and Waddell fields have already been discovered (in 1926 and 1927, respectively). The Church and Fields pool in Crane County and the Hendricks pool in Winkler County were discovered in 1926 by random drilling. The Yates pool, discovered in 1926 by the Transcontinental Oil Company and Mid-Kansas Oil and Gas Company on the recommendation of Ray V. Hennen and Frank R. Clark, underlies an anticline mapped on Cretaceous limestone.

## STRATIGRAPHY

Detailed descriptions of the stratigraphy and areal geology of West Texas have been published.[2]

Briefly, the section in the oil fields is as shown in Table I.

TABLE I

STRATIGRAPHIC SECTION IN WEST TEXAS OIL FIELDS

| | | |
|---|---|---|
| Lower Cretaceous | Limestone, sandstone | Locally absent; thicken to south |
| *Unconformity* | | |
| Triassic | Red beds | Locally absent |
| *Unconformity* | | |
| Permian | Red beds, salt, gypsum, dolomite, etc. | 600–5,000 feet thick |
| *Unconformity* | | |
| | Limestone dolomite ("Big Lake Big lime") | 3,500+ feet thick |
| *Unconformity* | | |
| Pennsylvanian | Shales, etc. | Not explored |

[1] E. C. Edwards and L. W. Orynski, "Westbrook Field, Mitchell County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 467–76.

[2] H. W. Hoots, "Geology of a Part of Western Texas," *U. S. Geol. Survey Bull. 780*, 1926; E. H. Sellards and L. T. Patton, "The Subsurface Geology of the Big Lake Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), pp. 365–81; E. C. Edwards, "Stratigraphic Position of the Big Lime of West Texas," *idem*, Vol. 11 (1927), pp. 721–28.

All of the oil production on the west side of the West Texas Permian basin has come from the top of the Permian limestone series, which is called the "Big Lake Big lime" to distinguish it from the producing horizon at Amarillo, the "Amarillo Big lime," and from the limestone which produces in the Westbrook field of Mitchell County on the east side of the basin, the Wichita-Albany group. The "Big Lake Big lime" has been correlated by some geologists with the Blaine gypsum which crops out at Amarillo (known there as the Alibates dolomite), and which is about 1,500–1,700 feet higher stratigraphically than the "Amarillo Big lime." Everywhere around the basin the limestone series rests on, or grades into, the Pennsylvanian, and therefore the uncertainty of correlation affects the top only. The "Big Lake Big lime" seems to be equivalent to the "Big lime" at Artesia, but no wells have been drilled sufficiently deep between Artesia and Amarillo to make correlations definite.

The essential difference between Amarillo and West Texas–Artesia is that the oil at Amarillo occurs in porous horizons at or near the base of the limestone series and also in arkose against and above the granite, whereas the oil in West Texas occurs in oölitic and porous dolomite at or near the top of the limestone series. The possibility of oil at the base of the series in West Texas is not known.

## STRUCTURE

Geology has played a very important part in the discovery of new fields after Big Lake showed the presence of oil. A large part of West Texas is on an alluvium or gravel-covered plain which supports a scattered growth of mesquite and other spiny bushes. The oil fields are near the northwestern edge of the Edwards Plateau—a tableland underlain by limestone of Cretaceous age. North of it outcrops of Triassic Red beds are few in number and uniformly unsatisfactory for detailed structure work. Hence surface geological work has been confined to the Cretaceous. The plains of the Llano Estacado north of the Edwards Plateau are examined by various geophysical devices. Subsurface geology has played a more important part in the discovery of these oil fields than anywhere else in the Mid-Continent region.

Structural work is beset with many difficulties, the chief of which is the presence of three unconformities. Many anticlines in the Cretaceous have been drilled and wells located on some have produced oil, but most of them have produced great volumes of sulphur water (one well flows 6,000 barrels a day).

Underground geology is known well in the oil fields, but poorly elsewhere. All the fields have been found to be anticlinal and to occur on the summits of buried hills and ridges. Their tectonics cannot be revealed at present, but the structure is not as simple as is indicated by published maps and sections. A structure contour map of the Church & Fields–McElroy area is reproduced by permission of the *Oil and Gas Journal* as an illustration of the type of anticline which is being found by the drill (Fig. 2). The full extent of the structure is not yet known.

Folding took place at the close of Pennsylvanian sedimentation in the Glass Mountains, 50 miles south of Fort Stockton, and developed northeast-southwest axes. Downwarping of the West Texas basin followed this folding and the subsequent planation of the older strata. The Amarillo Mountains stood as a barrier in the early Permian sea. The basin subsided unevenly and fragmentation on a broad scale gave rise to unconformities and to structural hills and ridges which were later buried. Some of these ridges were covered by a very thin salt red-beds section.

The Triassic rests unconformably on the uppermost Permian and is approximately parallel to it structurally. The Lower Cretaceous was deposited on a peneplaned surface by progressive overlap. Folding took place again in post-Lower Cretaceous time.

## ACCUMULATION

The significant feature of this accumulation is that the oil occurs in porous limestone and dolomite (oölitic in part) on buried hills from a few feet to 500 feet below the top of the limestone. The biggest producing wells in the world and the fields with the largest yield per acre have been on buried limestone ridges or associated with salt domes, and the cap rock of salt domes is analogous to the porous limestone of buried hills. Limestone or dolomite which is not associated with unconformities is an unsatisfactory reservoir throughout broad areas.

Sulphur gas is found everywhere in the Permian limestone and in higher horizons, generally in solution in the water and oil. Gas is commonly found above the oil. Below the basal Cretaceous sand or ground water in the Triassic all the water is sulphur water. All the oil smells strongly of sulphur, in contrast to the oil produced elsewhere in Texas, and tanks of West Texas oil on the Gulf Coast can be detected from afar by the odor.

## PRODUCTION

A list of the fields and the approximate depth of production is given in Table II.

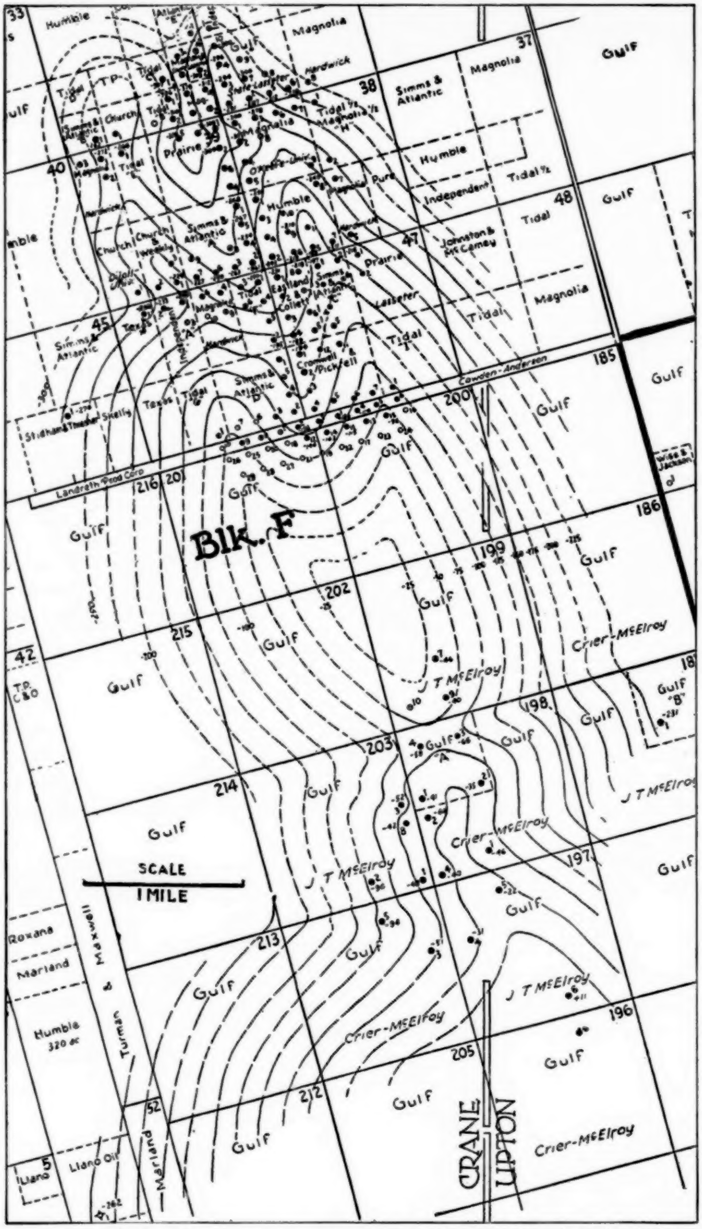


FIG. 2.—Subsurface structure-contour map of the Church and Fields-McElroy pools, Crane County, Texas, contoured on the top of the "Big Lake Big lime," the pay horizon. Contour interval, 25 feet; datum, sea-level. Drawn by G. F. Aldrich, of the Independent Oil and Gas Company, and reproduced by permission of the *Oil and Gas Journal* (issue of July 14, 1927) and of the Independent.

The Big Lake wells had an initial yield as high as 8,000 barrels a day. The size of recent large discovery wells is comparable, but has been judged from production over a few hours or days because of inadequate storage facilities. One well at Yates, only 1,000 feet deep, flowed 10,200 barrels in one day and another well was estimated to have a capacity of 20,000 barrels a day. The first wells in the Church & Fields pool were small, but the biggest wells in the southern extension flowed at the rate of 7,000 barrels a day. In the McElroy field the wells have had an average initial production exceeding 1,000 barrels.

TABLE II

PRODUCTION FROM WEST TEXAS FIELDS

| | Depth Pay (Feet) | No. Oil Wells July 1, 1927 (Approx.) | Daily Production July 1, 1927, Bbls. (Approx.) |
|---|---|---|---|
| Big Lake | 2,900–3,100 | 189 | 24,000 |
| World | 2,500–2,700 | 27 | 1,400 |
| McCamey | 1,800–2,300 | 258 | 21,000 |
| McElroy | 2,800–2,900 | 140 | 62,500 |
| Church & Fields | 2,900–3,200 | | |
| Hendricks | 2,700–3,100 | 5 | 1,300 (Wells pinched in) |
| Yates | 1,000–1,500 | 11 | 4,500 (Wells pinched in) |
| Waddell | 3,200 | ........ | ........ |

Big Lake, covering about 6 square miles, is a wonderful field, but the World pool, 14 miles distant, is a great disappointment because of low porosity and small wells. McCamey is a name applied to a producing area about 12 miles long and one-half mile to one mile wide. Sulphur water has affected all the wells and the yield per acre will be low. Church & Fields, together with McElroy, is already 7 miles long and 2 miles wide. Edge wells are affected by water. The other fields are undefined. Yates promises to be one of the greatest shallow fields ever discovered.

The gravity of the oil in these fields ranges from 31° at McElroy and Yates pools to 39° Bé. at Big Lake. The price is low because of the sulphur content, distance from the Gulf Coast, and overproduction.

SIDNEY POWERS

TULSA, OKLAHOMA
September 6, 1927

## A CORRECTION FOR WELL LOGS

It is customary in the process of oil well drilling by a standard-tool rig to measure the depth of the hole as development progresses by the use of the sand line. This is accomplished by "stringing over" or attaching targets to the sand line at the rig floor and at the sand line reel and directly measuring off the intercepted distance from the sand reel over the crown block pulley to the rig floor. This distance is taken as the unit of measure.

It is seldom that this unit, the "run-over," is accurately established. As a result an accumulative error is introduced which for shallow wells is of little consequence but for deep tests becomes an error of considerable magnitude.

When an accurate determination of the depth of a hole is required for the purpose of placing a shot, establishing a production horizon, or for completion of a contract, the steel line is employed. It is rare that the steel line measure (S.L.M.) agrees with the "run-over" measure, and for holes of 3,000 to 5,000 feet it is not uncommon to have a difference of 50 to 100 feet or more for bottom hole. In view of the fact that samples have been assigned depth indicators by the "run-over" method, a correction should be made before careful correlation is attempted. This correction is very easily and quickly made by use of the following formula:

$$t=r\frac{T}{R}$$

where the total depth

Run-over $=R$ in feet
Steel tape $=T$ in feet

and the depth of any sample

Run-over $=r$ in feet
Actual depth $=t$ in feet

Calculate the ratio $\frac{T}{R}$, which then becomes the constant for the well, $K$, and is less than unity when the actual depth of the well is less than the "run-over" reading, and vice versa.

Then $$t=r\cdot K.$$

Or, as an alternative, the computation may be made in the following form:

$$D=R-T, \text{ or } T-R,$$

=numerical difference between run-over and steel tape measure, taken positively; then we have,

$$t=r-r\frac{D}{R}$$

when $R$ is greater than $T$, and

$$t=r+r\frac{D}{R}$$

when $R$ is less than $T$.

For a well having an excessive difference for bottom-hole measure it is not necessary to correct for all samples, but only for those which indicate a change of formation or some horizon marker that is essential in the compilation of a log for correlation. It should be borne in mind that this correction takes care only of the cumulative error introduced by the inaccuracy established by the initial run-over measure, and does not accommodate the numerous irregularities that may be introduced and can only be corrected for by an intimate knowledge of the history of the well.

W. B. Lang

U. S. Geological Survey
Roswell, New Mexico
August 11, 1927

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## AN OIL SEEP IN NORTH-CENTRAL NEVADA

During the summer of 1926 the writer had the opportunity of examining an oil seep in the state of Nevada. This seep is on the Bruffy Ranch in Sec. 11, T. 27 N., R. 52 E., Eureka County, on the west side of the Pinon Range about 30 miles south of the town of Palisade. It lies about 15 miles farther south than the asphaltite deposit reported by Robert Anderson in *U. S. Geological Survey Bulletin 380H*, and occurs in the same series of strata. These strata are very similar to the upper beds of the White Pine shale formation (Mississippian) of Central Nevada, which are very bituminous in places, and are, no doubt, of the same age.

The oil seeps out at the outcrop of fractured, black, calcareous shales which apparently are dipping eastward into the mountains. These shales are in fault contact with older, highly fractured, massive limestones, the attitude of which could not be definitely determined in the brief examination made. Farther south along this fault zone, at intervals for a half mile or more, hot sulphur springs arise which have deposited tufa that

forms a westward-facing bench. At the west the valley is filled with Tertiary and later beds. As this whole area is one of considerable faulting, fracturing, and igneous activity, it is consequently highly mineralized. At Union, four miles southeast of the Bruffy Ranch, several metal mines were in operation.

The oil seep was discovered by R. V. Bruffy in digging out a water hole in order to develop water for a small irrigation system. As soon as the cover of soil and mud was removed the heavier parts of the oil began to ooze out upon the surface of the water in black tarry masses half the size of an egg. This oil was a heavy, black, viscous substance of very low gravity.

This occurrence of oil, and the presence of asphaltite deposits farther north in the same formation are of interest in that they show a possible source of commercial oil in a state which as yet has no oil production.

CHARLES S. LAVINGTON

DENVER, COLORADO
August 21, 1927

## PERMIAN FOSSILS FOUND IN DRILL SAMPLES PURPORTED TO BE BELOW THE WELCH CHERT FROM WELL IN DICKINSON COUNTY, KANSAS

In the latter part of May, 1927, some samples were brought from the Leeward well in the northeast corner of Sec. 23, T. 13 S., R. 3 E., Dickinson County, Kansas. Among these were some well-preserved fossil brachiopods in a sack labeled as coming from this well at a depth of 2,240 feet. The writer is no paleontologist, but as it seemed obvious that these fossils could not have come from a drilling well, he, assisted by J. S. Barwick, made a small collection of fossils from surface exposures of the Winfield limestone, which outcrops in the vicinity of the well.

On August 10 these fossils were sent to George H. Girty, of the U. S. Geological Survey. His identification is as follows:

Lot 1 (from surface exposure of Winfield limestone): *Septopora biserialis*, *Derbya multistriata*, *Composita subtilita*.

Lot 2 (from surface exposure of Winfield limestone): *Derbya multistriata*, *Productus semireticulatus* var., *Composita subtilita*.

Lot 3 (this is the sample labeled as coming from the well at a depth of 2,240 feet): *Derbya multistriata*, *Composita subtilita*.

It is obvious that the two types of fossils found in this last sample were found in each of the surface samples.

The following paragraph is quoted from Dr. Girty's letter:

> If I were to depend on the paleontologic evidence alone, I should say that all three faunas were of the Permian age and probably early Permian, older, let us say, than the Marion and of course younger than the Pennsylvanian. Lots 1 and 2 you tell me are from surface material, and lot 3 from a cable tool well 2,240 feet below the surface, the same surface essentially which furnished the two other lots. It seems to me practically certain that one of these facts is in error. Viewed either from the mechanical or the paleontologic standpoint, lot 3, it seems to me, can hardly have had the source claimed for it. Not only are the specimens more or less perfect, some of them measuring 30 millimeters or more in diameter, but I should say that it was practically impossible, or at least wholly incredible, that the fauna of lot 3 could have come from a depth of 2,240 feet, even if it came from a drilled well at all. If the surface rock is the Winfield limestone, as it appears to be, the depth assigned to lot 3 would place its horizon far down in the Pennsylvanian so that even if an allowance is made for variation in the thickness of the rocks and for human fallibility, I seem safe in saying that the facts as stated are absolutely irreconcilable.

Lot 3, from a depth of 2,240 feet in this well, is either below, or at the base of, the Welch chert, the top of which is found at a depth of about 2,183 feet. If one accepts the fact that this sample came from a depth of 2,240 feet, he must then assume that the Welch chert is lower Permian in age. Such an assumption is obviously incorrect.

A reasonable assumption of the facts in this case is that the driller had collected a few surface fossils and carelessly placed them in a sample bag intended for another sample. To anyone who is familiar with the methods used in collecting samples this error would not appear very remarkable. The driller feels that he is hired to drill the well, and that the collecting and saving of samples is a part of the work which is entirely unnecessary and is thrown on his shoulders in addition to such work as he is paid for. The writer has seen numerous batches of drill samples scattered hither and yon about a rig floor, usually kept on the inside of a thread protector, and he has frequently collected samples preserved in such manner, with the driller or tool pusher recalling from memory the depth at which each sample was taken. It is true that he had some qualms regarding the accuracy of this sample at that time, but since they were the best available, he took them anyhow. There is no doubt that in many cases many samples have been incorrectly labeled and are not sufficiently satisfactory to give correct correlations. In cases where one has a vast variety of data from different wells he may overcome the errors due to the mixing of samples by assuming that one sample which did not agree with others in the same part of the section had become incorrectly labeled.

While in this case it is admitted that the error was so obvious that anyone would recognize it, it appears to the writer that many such cases may arise which are not so obvious.

It is the conclusion of the writer that no general or widespread correlations may safely be made from well samples unless one has conclusive data from several wells, and not in any case from one sample from one well.

C. R. Thomas

Skelly Oil Company
Eldorado, Kansas
September 2, 1927

# DISCUSSION

## STRATIGRAPHIC DISTRIBUTION OF PETROLEUM

I note the following inexactitudes and omissions occurring in Mr. F. J. Fohs' "Chart of Stratigraphic Distribution of Petroleum" which appeared on page 764, Vol. 11, No. 7, July, 1927.

ITALY has minor and prospective production from the Cretaceous.

SICILY's minor and prospective production is confined to the Eocene and Miocene, there being none from the Cretaceous.

ROUMANIA's major production is from the Pliocene, with minor or prospective production from the Eocene, Oligocene, and Miocene.

SPAIN has minor or prospective production from the Cretaceous and Eocene.

ALGERIA, MOROCCO, TUNISIA have minor or prospective production from the Eocene and Miocene only.

H. F. CROOKS

"ROMANO-AMERICANA," TELEAJEN WORKS
PLOESTI, ROUMANIA
August 10, 1927

# REVIEWS AND NEW PUBLICATIONS

*Grundfragen der vergleichenden Tektonik* (*Principles of Comparative Tectonics*). By H. Stille. Gebrüder Borntraeger, Berlin W. 35, 1924. Pp. vii+443; figs. 14. Price, M. 22.50.

Stille's book which treats of the principles of comparative tectonics is one of the most valuable existing summaries of the present knowledge of the form, structure, and development of the crust of the earth. It contains an enormous amount of information about orogenic and epeirogenic movements, their causes, effects, relationships, and the phases of mountain-building during the past geologic eras.

Part I deals with the explanation of fundamental principles of tectonics. The author, for example, explains the terms "orogeny" and "epeirogeny." The orogenic movements are characterized by their comparative shortness, causing structural modification of the strata (main types: anticline and syncline). Epeirogenic movements, on the other hand, continue over a long geologic time, affecting broad areas without changing the structural configuration of the strata (main types: geanticline and geosyncline).

To the reviewer, the most interesting part of the book is Part II, bearing the title "Research on the Principles of Orogeny." The abundance of new striking ideas about the complex problem of orogenic movements and the great amount of information regarding the structural features of the earth's crust make this part the most valuable to every student of orogenic disturbances. It is not the reviewer's intention to mention all the problems discussed. This would by far exceed the space allowed for the review. The selection of a few questions of general interest will better arouse the attention. Stille's definition for orogenesis comprises all kinds of structural modification. Hence he obtains four main groups of orogenic movements: (1) mountain-building by lateral overthrusts, (2) mountain-building by folds, (3) mountain-building by fault-folds, and (4) mountain-building by block faults.

The author's ideas of the causes, effects, relations, and phases of mountain-building are expressed in six fundamental laws. His first law states that orogenesis is confined to very definite periods of the earth's history, which possess more or less world-wide significance. The law about the "contemporaneity of orogenic forms" expresses the idea that all the different types of orogenic structures might develop in the same phase of orogenic movements. The different types, however, do not occur in direct contiguity. Rather are they connected by a long line of intermediate forms, having the extreme types at the

ends of the series, which comprise the mountains built by overthrust and the mountains built by block faulting. These conditions are expressed in the third law about the "connection of the orogenic types." The fourth law deals with "orogenic upward movement" and explains that every orogenic structure, therefore—not only folds, but also fault-folds and block faults—are caused by upward movement relative to the sea-level. The laws 2–4 consequently lead the author to his fifth law, which states that all the orogenic movements are the result of the same orogenic force, that is, tangential pressure. The type of mountain-building is primarily determined by the nature of the affected rocks. In other words, no different forces produced the different orogenic types, but the same forces worked differently, corresponding to the varied conditions of the rocks affected. This is the substance of the sixth law. In this sense folding must be regarded as the characteristic type of reaction of the more plastic rocks, faulting of the more rigid rocks. A salt upthrust, which the author regards as a phenomenon of normal tectonics, represents a type of reaction of highly plastic material. The constitution of the earth's surface changes with time and with the lapse of orogenic, epeirogenic, volcanic, and exogenic events. This change of the structural constitution varies at one certain place, also the types of orogenic reaction from one phase of disturbance to another. On the whole, we observe a process of evolution tending to increase the resistance of folding of the rocks of the earth's crust which have already been folded several times, and consequently a tendency for progressive formation of simpler and simpler orogenic types, until every orogenic reaction is suppressed.

Epeirogenic events are discussed in Part III. The main forces for epeirogeny are the same as for orogeny, namely, tangential pressures. The movements of the seas furnish the diagnostic criteria for reaching an understanding of epeirogenic phenomena. These movements reveal certain primary tendencies in specific epochs, regardless of the area of the sea basin. Therefrom originate certain rules, called in German *Kanon*, about the enlargement and contraction of the sea from one time epoch to another, indicated by regressions and transgressions. On the whole, we see that orogenesis leads to general regressions; epeirogenesis, to general regressions and transgressions. The law (*Kanon*) of the movements of the sea may be regarded as indicative of the changing intensity of the earth's tangential pressure.

Stille's book is the result of a tremendous amount of work. To the reviewer it is one of the most comprehensive works dealing with comparative tectonics. Its study will be of the greatest benefit to all students of the subject. The author gathers all evidence in favor of his ideas, dicusses and criticizes fairly theories of other writers that do not agree with his own. In his opinion, the tangential pressure must be regarded as the principal force for orogenic, as well as epeirogenic, movements. Isostasy is only a secondary factor in orogenic mountain-building, but has, however, a certain influence in epeirogenesis. The book is written clearly and understandingly, but a greater number of illustrations would

improve its value. The author, indeed, does not regard his book as a final word on the complicated phenomena of the movement of the earth's crust, but as a step forward in deciphering one of the most interesting geological problems.

CHARLES RYNIKER

TULSA, OKLAHOMA
July 19, 1927

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"Electrical Investigations in the Oilfields of Texas." By N. GELLA, *Petroleum Zeitschrift*, Berlin, Band 23, Nr. 21, July 20, 1927, pp. 885-88.

The author gives a very optimistic description of the results of the application of the "Elbof" electrical method on the Gulf Coast, and states that the results have definitely shown the ability of the method to outline the edge of the dome and the depth to the top of the dome and to the flanks of the dome down to a very considerable depth, and to indicate the presence of oil sands. Dr. Gella's conclusions in regard to the method, of which he is the inventor, would seem to be much more optimistic than the results to date in the Gulf Coast would warrant. The method was tried out exhaustively by one of the two oil companies which are doing the most geophysical work and who are the most thorough in their trying out of geophysical methods, and was given an adverse verdict. According to apparently authentic report, for example, a location was made at which the method definitely indicated a flank oil sand at about 3,000 feet; the location was on top of the dome, however, and the test well went into the salt at about 1,000 feet. Theoretically the method seems sound and would seem to offer distinct possibilities for the future as a direct method of finding oil in contrast to our present indirect methods of finding structure and then hoping that there is oil on it and that we are drilling in the right place on it. But the instruments or the technique, or both, of the "Elbof" method at present do not seem to have been perfected quite sufficiently for practical application of the method to prospecting for oil.

D. C. B.

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## NEW PUBLICATIONS

### GENERAL

"Isostasy," by William Bowie. E. P. Dutton & Co., 681 Fifth Avenue, New York City. Pp. 275; illustrated. Price, $5.00.

"Correlation of Geologic Formations between East-Central Colorado, Central Wyoming, and Southern Montana," by Willis T. Lee. *Professional Paper 149, U. S. Geologic Survey*. Maps and photographs. Superintendent of Documents, Washington, D.C. Price, $0.50.

*Tropisches Buschleben* (*Life in the Tropical Bush*), by Otto Stutzer. Dietrich Reimer (Ernst Vohsen) Aktiengesellschaft, Verlagsbuchhandlung, Berlin, SW. 48, Germany. Price, M. 5.

ALASKA

"The Iniskin-Chinitna Peninsula and the Snug Harbor District, Alaska," by Fred H. Moffit. *Bulletin 789, U. S. Geological Survey,* Washington, D.C., 1927. Pp. 71; maps and photographs. Sections on petroleum, pp. 48–54. Free.

CANADA

*Summary Report, 1926, Part B,* Geological Survey, Ottawa, Canada, 1927. Pp. 57, with maps. Contains "Turner Valley Oil Area, Alberta," by G. S. Hume; "Geological Structure in the Western End of Cypress Hills, Alberta," by W. S. Dyer; "Oil and Gas Prospects in Southern Saskatchewan," by W. S. Dyer; "Geology and Oil Prospects in the Vicinity of Riverhurst, Saskatchewan," by P. S. Warren; and "Deep Borings in the Prairie Provinces and Northwest Territories," by E. D. Ingall.

OKLAHOMA

*Oil and Gas Fields of the State of Oklahoma,* map compiled and drawn by Lewis B. Pusey under the direction of G. B. Richardson, 1927. U. S. Geological Survey, Washington, D.C. Scale, 1:500,000. Size 64×34 inches. Paper. Price, $0.50.

The following reports may be obtained from the *Oklahoma State Survey,* Norman, Oklahoma:

"Cleveland and McClain Counties," by G. E. Anderson. *Bulletin 40-N.* Price, postpaid, $0.30.

"Kingfisher and Canadian Counties," by W. C. Kite. *Bulletin 40-O.* Price, postpaid, $0.30.

"Structural Trends in Southern Oklahoma," by LaVerne Decker. *Bulletin 40-P.* Price, postpaid, $0.30.

"Mineral Resources in Oklahoma," by John S. Redfield. *Bulletin 42.* Price, postpaid, $0.10.

ILLINOIS

"Illinois Petroleum." *Press Bulletin Series No. 11, State Geological Survey,* Urbana. Recent development in oil fields near Jacksonville, Morgan County. Map and cross-section. Price, $0.25.

MONGOLIA

*The Geology of Mongolia,* by Charles P. Berkey and Frederick K. Morris. G. P. Putnam's Sons, 2 West 45th Street, New York City. 44 plates, 161 text illustrations, 6 maps in pocket. Price, $10.00.

TEXAS

*Oil and Gas Fields of the State of Texas,* map compiled and drawn by Lewis B. Pusey under the direction of G. B. Richardson, 1927. U. S. Geological Survey, Washington, D.C. Scale about 12 miles to an inch. Size, 74×57 inches. Paper. Price, $0.50.

UGANDA

"Petroleum in Uganda," second (revised) edition. Geological Survey Department, Uganda Protectorate. Crown Agents, 4, Millbank, London, S. W. 1. Price, 10*s*.

## THE ASSOCIATION LIBRARY

Headquarters acknowledges library accessions:

GENERAL

*From Sidney Powers:*

*Der Geologe*, No. 41, June, 1927.

*Geologie*, Catalog No. 193, Max Weg, Geological Publications.

*From American Oil Men's Association:*

*Petroleum Reference Book*, 1927.

*From A. C. Heiland:*

"Geophysical Methods as Applied to Prospecting for Oil and Gas."

"Geophysical Methods in Mining."

"Prospecting with the Magnetometer."

CANADA

*From the Geological Survey, Canada:*

*Memoir 151*, 1926. "Minto Coal Basin, New Brunswick," by W. S. Dyer.

*Memoir 152*, 1927. "St. Urbain Area, Charlevoix District, Quebec," by J. B. Mawdsley.

*Summary Report, 1926, Part B*, 1927.

*Summary Report, 1925, Part C*, 1927.

# THE ASSOCIATION ROUND TABLE

## APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

### FOR ACTIVE MEMBERSHIP

Harold K. Armstrong, Los Angeles, Calif.
W. H. Emmons, Art R. May, M. G. Edwards
Alfred H. Bell, Urbana, Ill.
K. C. Heald, Gail F. Moulton, Theodore A. Link
Norman W. Brillhart, Cisco, Tex.
Ford Bradish, V. E. Monnett, E. P. Hindes
Victor Cotner, Lovell, Wyo.
Edwin Binney, Jr., W. E. Wrather, Wilbur A. Nelson
Charles L. Dake, Rolla, Mo.
Lawrence J. Zoller, V. H. Hughes, Joseph M. Wilson
James S. Hudnall, Brownwood, Tex.
Ulrich R. Laves, M. M. Garrett, Robert N. Kolm
Olaf P. Jenkins, Batavia, Java, D.E.I.
C. S. Corbett, William B. Heroy, C. Naramore
Graham B. Moody, Colorado, Tex.
S. H. Gester, H. J. Hawley, E. J. Young
Paul C. Murray, Los Angeles, Calif.
E. R. Ames, Henry J. Hawley, Frank S. Hudson
George W. Pirtle, Brownwood, Tex.
James H. Gardner, Ulrich R. Laves, E. L. Porch, Jr.
Charles L. Rankin, Shreveport, La.
W. C. Spooner, S. C. Stathers, L. P. Teas

### FOR ASSOCIATE MEMBERSHIP

Russell H. Dicken, Duncan, Okla.
Robert N. Kolm, M. M. Garrett, Charles E. Decker
Daniel G. Emrick, Amarillo, Tex.
H. B. Fuqua, Ben C. Belt, C. E. Yager

Kenneth A. Johnston, Denver, Colo.
Charles M. Rath, Harry A. Aurand, R. Clare Coffin

FOR TRANSFER TO ACTIVE MEMBERSHIP

Cunningham L. Griffith, Houston, Tex.
Charles Laurence Baker, J. M. Vetter, Paul Weaver

Hugh W. McClellan, Bartlesville, Okla.
John M. Nisbet, W. L. Walker, A. F. Morris

Robert H. Palmer, Seattle, Wash.
Eugene A. Stephenson, Jerry B. Newby, David White

Basil B. Zavoico, Enid, Okla.
J. M. Lilligren, Roland L. Clifton, Wesley G. Gish

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## BOUND VOLUMES OF THE BULLETIN

The demand for back numbers and complete sets of the *Bulletin*, not only from members of the Association, but from outside sources such as government bureaus, educational institutions, the legal profession, and investment concerns, has so taxed the supply on hand that headquarters can no longer offer a full set for sale. Several numbers are not available either in paper or cloth bound. They may be classed with the rare copies of our state and federal bureaus that are now the treasured possessions of a few libraries. Because of this continued drain on the stock of these valuable publications, the few remaining complete sets of the years 1921 and 1922 (Vols. 5 and 6 which were originally published in an odd size) have been trimmed down and bound in green cloth to match the volumes of recent years. These two newly cloth-bound volumes are now available at $12.00 a volume. Each contains the complete 6 numbers, which originally sold at $2.00 a number in paper covers.

Members who plan to complete their library sets of the *Bulletin* should check their missing numbers or volumes and order before the supply is exhausted.

A full set of the *Bulletin* through 1926 (except Vol. 1 and Vol. 4, No. 1) may still be obtained in uniform cloth binding (except Vols. 2, 3, and 4, which are in paper) for $96, postpaid. The Complete Index is $2.00 extra. Write to Association Headquarters, Box 1852, Tulsa, Oklahoma.

# AT HOME AND ABROAD

## CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

Association headquarters, which has been in rooms on the second floor of the public library building during the past year, will be moved into somewhat larger offices next month on the fifth floor of the new Tulsa Chamber of Commerce and Tulsa Club building recently completed at the corner of Cincinnati Avenue and Fifth Street.

RALPH D. MITCHELL is with the D'Arcy Exploration Company, Ltd., % Señor José M. Escobar Salaz, Puerto Berrio, Colombia, S. A.

RICHARD T. LYONS was temporarily in charge of the land department of the Skelly Oil Company in Tulsa in September.

E. GAIL CARPENTER has resigned his position with the Sinclair Oil & Gas Company, at Enid, Oklahoma. He is now with the Foster-Reiter Company at Tulsa.

N. H. DARTON, of the U. S. Geological Survey, spent part of the summer at Marathon, Texas, examining the Marathon uplift.

W. D. HAMM, of the Roxana Petroleum Corporation, is stationed at Dallas in charge of work in northwestern Texas.

J. BRYAN LEISER, of the Roxana Petroleum Corporation at Tulsa, is in charge of subsurface work in Kansas.

B. L. LAIRD, superintendent of the land and geological department of the California Company, with Texas headquarters at Colorado City, was in Fort Worth recently on company business.

J. M. PATTERSON has moved from Amarillo to Hugo, Oklahoma. Mr. Patterson is with the Pure Oil Company.

STUART WELLER, professor of paleontologic geology and director of Walker Museum at the University of Chicago, died suddenly from heart failure while on a field trip with students, August 5, 1927.

H. R. THORNBURGH, of San Angelo, Texas, left the Roxana Petroleum Corporation on August 1, to enter consulting work in Dallas, Texas.

A. R. DENISON, of the Amerada Petroleum Corporation, has been transferred from Tulsa to San Angelo, Texas.

The Illinois State Geological Survey has recently received from the Legislature, with the approval of the Governor, an increase over its usual appropriation which will permit an extension of specialization in petroleum engineering and geological engineering, and the undertaking of a comprehensive paleobotanic study of the Pottsville series, in addition to its regular program of

stratigraphic, glacial, and economic studies. The paleobotany of the Pottsville series will be studied by Dr. David White. The previous appropriation of $50,000 for topographic mapping was continued.

GERALD WESTBY, of the Empire Gas and Fuel Company at Denver, Colorado, has been at the Bartlesville, Oklahoma, office the past few months.

ALAN M. BATEMAN spent part of the summer in Alaska.

JAMES L. DARNELL, engineer, has moved from 170 Broadway to 420 Lexington Avenue, New York City.

FRED B. ELY, consulting geologist, Room 1117, 135 Broadway, New York City, returned last August from an examination trip of two months in Venezuela.

J. P. SCHUMACHER, of the Torsion Balance Exploration Company, has returned from a trip to Europe and has brought with him a number of new torsion balances for use in this country.

EUGENE FEKETE, who was Baron Eotvos' assistant in all but his earliest work, returned with Mr. Schumacher and will join the staff of the Torsion Balance Exploration Company.

A. S. HENLEY, chief geologist of the Houston Oil Company, is on a six months' leave of absence on account of ill health.

FRANK W. DEWOLF, until recently chief geologist of the Humphreys Corporation, has been made general manager of the Border Research Corporation and will maintain his headquarters at Houston, Texas.

S. W. DASZYNSKI went to Venezuela the past summer and is now in the geological department of the Venezuela Gulf Oil Company, Apartado 234, Maracaibo.

U. R. LAVES, of the Roxana Petroleum Corporation, has moved from Abilene to Kerrville, Texas.

SIDNEY PAIGE has been appointed administrative geologist for the Amerada Petroleum Corporation at Fort Worth, Texas.

R. A. LIDDLE, geologist for the Pure Oil Company at Mexia, Texas, spent part of August in the Adirondack Mountains.

THERON WASSON, chief geologist of the Pure Oil Company, made a brief trip to Venezuela last month.

D. B. MYERS, assistant chief geologist of the Union Oil Company of California, was in Oklahoma and Texas in July and August.

WALLACE C. THOMPSON, geologist for the Sun Oil Company at Wichita Falls, has been in the Dallas office of the company the past two months during the absence of F. H. LAHEE, chief geologist, who was in Europe.

E. L. FIPPS resigned from the geological department of the Gypsy Oil Company last August. Mr. Fipps' home address is Salem, Missouri.

MURRAY L. NEUMANN, chief geologist of the Carter Oil Company, Tulsa, took a vacation in Colorado in August.

Three of the Association's bibliophiles, E. DeGolyer, W. E. Wrather, and James L. Gartner, have built new houses to accommodate their growing libraries.

Leslie S. Harlowe, chief geologist of the Louisiana Oil Refining Corporation at Shreveport, and George Pryor, of the geological department, were in Oklahoma in August in connection with the corporation's production in the southern part of the state.

F. B. Plummer, formerly administrative geologist for the Amerada Petroleum Corporation at Fort Worth, spent September on a vacation in New Hampshire.

Hubert E. Bale has resigned from the geological department of the Texas Pacific Coal and Oil Company at Oklahoma City.

Rud. Brauchli, of the Anderson-Prichard Oil Corporation, Oklahoma City, Oklahoma, spent the summer in Switzerland.

B. F. Robinson is chief geologist of the Red Bank Oil Company, Castle Building, Tulsa.

O. M. Edwards is geologist for George W. Snedden of Tulsa and has been working in San Angelo, Texas.

F. Park Geyer, formerly of the Marland Oil Company, is operating at San Angelo.

George S. Buchanan, formerly paleontologist with the Carter Oil Company, has resigned to do consulting work in Tulsa. Mr. Buchanan's office is 1102 Atlas Life Building.

W. H. Foster is vice-president of the Reiter-Foster Oil Company at Tulsa.

D. F. Neufer is micro-paleontologist with the Carter Oil Company at Tulsa.

Marion H. Funk has returned from Trinidad and is again with the Louisiana Oil Refining Corporation at Shreveport.

W. L. Goldston represents Cranfill & Reynolds in Cisco, Texas.

Floyd B. Kerns has resigned from the Texas Pacific Coal and Oil Company, Oklahoma City, Oklahoma.

Henry N. Toler has returned from Colombia and is in the employ of The Texas Company, 17 Battery Place, New York City.

R. O. Rhoades, of the South American Gulf Oil Company at Cartagena, Colombia, returned to the United States. His address is 196 Vennum Avenue, Mansfield, Ohio.

M. B. Arick may be addressed at Box 1547, University Station, Austin, Texas.

Carlton M. Carson, geologist and paleontologist, is at Tampico, Mexico.

Ralph G. Lusk, recently graduated from Harvard with the degree of Doctor of Philosophy in Geology and Geography, died last July.

E. C. Case, of the University of Michigan, spent the summer in west Texas.

Stuart St. Clair, consulting geologist, has moved his office from 25 Broadway to Hudson View Gardens, New York City.

Joseph Jensen, of Los Angeles, California, made a trip through Texas in August.

W. W. Scott, of the Pure Oil Company, has moved from Mexia, Texas, to Tulsa, Oklahoma.

The U. S. Geological Survey has issued a revised oil and gas map of Texas. The previous edition was published in 1925.

F. Julius Fohs returned to New York in August after spending two and a half months in Europe, where he made a study of the oil possibilities of Sicily, a reconnaissance of the oil field of Amelia in northern Italy and of the oil fields and potash mines of the Hanover district in Germany. Mr. Fohs will now devote his full time to the interests of the companies with which he is closely affiliated—Humphreys Corporation, Olean Petroleum Company, and Red Bank Oil Company.

M. A. Neel is employed by the Marion Oil Company at Dallas, Texas.

Ronald K. DeFord, of the Midwest Refining Company, moved from Roswell, New Mexico, to 420 Rule Building, Amarillo, Texas, last month.

D. B. Hunter, of the Phillips Petroleum Company, has been transferred from Seminole to the Texas Panhandle, where he is stationed at Amarillo, succeeding G. S. Lambert, who has gone to Peru for the company.

Launcelot Owen has left England to take up an appointment in Venezuela and Trinidad.

Cornelius Schnurr has moved from Amarillo to Midland, Texas.

Fred P. Shayes, geologist for the Houston Oil Company, has been transferred from Beeville to the company's headquarters at Houston.

Elmer M. Rice is assistant paleontologist for the Pine Oil Company, Fort Worth, Texas.

R. B. Roark is with the Roxana Petroleum Corporation, Mayo Building, Tulsa, Oklahoma.

E. G. Leonardon, formerly of the Roxana Petroleum Corporation at Dallas, is now located with the Schlumberger Electrical Prospecting Methods, 25 Broadway, New York City.

A. W. Tiedemann, of the Royal Dutch interests, has been transferred from Mexico to Borneo. His address is care of Sarawak Oilfields, Ltd., Miri, Sarawak, British Borneo.

Edwin H. Hunt is with the California Petroleum Corporation at Calpet, Wyoming.

WALTER BURRESS, of the Mid-Continent Petroleum Company, is located at Midland, Texas.

WILLIAM HOEY is geologist for the Tidal Oil Company at Cisco.

CLIFTON M. KEELER is consulting geologist at Alpine, Texas.

D. J. EDSON, consulting geologist at Corsicana, Texas, is a frequent visitor at Fort Stockton.

BURTON HARTLEY, consulting geologist at Cisco, is working in west Texas.

HARVE LOOMIS, of Baird, Texas, is working at Ozona.

G. C. GESTER made an inspection trip through west Texas in August.

JAMES TITCHNER is an independent operator at Cisco.

D. H. EUBANK, geophysicist for the Gulf Production Company, is working in west Texas.

H. T. BECKWITH, consulting geologist, is living in San Antonio.

FRANK CARNEY, of the National Refining Company, has moved to west Texas.

W. V. HOYT is geologist for Cecil Canary at Cisco.

EDGAR OWEN, geologist for the Wentz Oil Corporation at Eastland, Texas, is a frequent visitor at Fort Stockton.

BEN C. BELT, of the Gulf Production Company at Fort Worth, is largely responsible for the discovery of the McElray and Waddell fields, west Texas. O. C. HARPER, formerly with the Gulf, assisted in discovering this remarkable line of folding prior to drilling for oil in the region. At the present time the fields along this line are judged to be among the most prolific oil reservoirs ever developed in the United States.

J. V. HOWELL has returned from a summer in the Canadian Northwest.

W. K. ESGEN is district geologist for the Humble Oil and Refining Company at Cisco.

W. A. J. M. VAN DER GRACHT, of the Marland Oil Company of Delaware, spent August in California.

R. A. CONKLING is working in Foard County, Texas.

W. A. MALEY is geologist for Cannon and Cannon at Fort Stockton.

J. R. PEMBERTON toured west Texas in a private car in August. It is reported that after an intensive study of birds' eggs for twenty years Bill has given up the idea that they are the source of oil and has been converted to the diatom hypothesis.

DOLLIE RADLER, administrative geologist for the Amerada Petroleum Corporation at Tulsa, spent her vacation in Arizona.

BRYANT ALLEN is in charge of the surface geological work of the Mexican Gulf Oil Company in Mexico.

E. W. AMES is engaged in consulting work at Cisco, Texas.

C. E. COOK, of the Dixie Oil Company, is stationed at Fort Stockton, Texas.

FRANK R. CLARK, of the Mid-Kansas Oil Company at Alpine, Texas, visited Fort Stockton in September.

D. R. SEMMES, consulting geologist at Cisco, spent the summer in the state of Washington.

W. R. BERGER, chief geologist of the Marland Oil Company of Texas, spent his vacation in Colorado.

E. L. PORCH has moved from Cisco to San Antonio.

RALPH ILSLEY, formerly micro-paleontologist with the Sun Oil Company, has accepted a similar position with the Roxana Petroleum Corporation at Dallas.

The Kansas Geological Society sponsored a Missouri-Iowa field conference, September 5–10, commencing at Columbia, Missouri, and ending at Decorah, Iowa, for the principal purpose of examining the Ordovician outcrop. E. B. BRANSON was leader of the party through Missouri, and GEORGE F. KAY through Iowa.

ERNESTO BARTH, geologist of the Bureau of Mines and Petroleum, La Paz, Bolivia, has prepared a report on the oil deposits of the Bolivian Chaco with special reference to areas drilled by the Standard Oil of Bolivia. Abstracts of this report and a map are published in *Oil Engineering and Technology* (London, July, 1927), pp. 245–48.

QUENTIN D. SINGEWALD has resigned as geologist with the Compania Transcontinental de Petroleo of Mexico to accept a position as assistant professor of geology at the Colorado School of Mines, Golden, Colorado.

MOSES M. KORNFELD has recently been placed in charge of the paleontological branch office of the Roxana Petroleum Corporation at Houston, which is maintained under supervision of FREDERICK FREI, head of the department of paleontological and heavy mineral work at Dallas headquarters.

RAUL ZUMELZU, mining engineer, published a paper, "El Petroleo en Bolivia," in *Revista Minera de Bolivia*, Oruro, Bolivia, December, 1926.

WALTER WOOLNOUGH, professor at Sydney University, is to make a thorough investigation of Australasian oil possibilities as a result of the decision of the Australian Federal Government to spend £100,000 to find oil supplies on the continent. Professor Woolnough will investigate New Guinea and Papua also.

OLIVER B. HOPKINS, of the Imperial Oil Company, Toronto, Canada, has two articles, "The Present Situation of Petroleum Production in Colombia" and "The Oil Fields of Ecuador in 1926," in the special South American number of

the *Petroleum Zeitschrift* of August 10, 1927, reprinted from the *Petroleum Times*. OTTO STUTZER, of Freiberg, Germany, also had an article, "Petroleum in Colombia," in the same issue of the *Zeitschrift*, reprinted from the *Hamburger Nachrichten*.

PAUL H. REAGAN, of Denver, Colorado, is engaged in geological work in Chile. His address is Casilla 17, Tocopilla, Chile, S. A.

K. C. HEALD, of the Gulf Companies, visited Fort Worth in August in the interest of research.

HENRY G. SCHNEIDER has been working in southern Mississippi for the Dixie Oil Company of Shreveport, Louisiana.

W. J. ACHNING has resigned from the Rio Bravo Oil Company to accept a position with the Roxana Oil Corporation at Houston.

DAVID J. CRAWFORD has moved from Dallas to Mexia, Texas.

J. E. EATON, consulting geologist of Los Angeles, is the author of an article, "Big California Increase in 1928–29," in the *Oil and Gas Journal* (September 1, 1927), p. 33.

PAUL D. TORREY, of the Northwestern Pennsylvania Producers Association of Bradford, published a paper on "Discoveries in Flooding Operations" in the *Oil and Gas Journal* (September 1, 1927), pp. 34 and 134.

THOMAS W. BUZZO has moved from San Angelo to Laredo, Texas.

RAE PREECE is stationed at Forth Worth.

C. M. VALERIUS, formerly with The Texas Company, is working for the Amerada Petroleum Corporation at San Angelo, Texas.

V. F. MARSTERS has moved to Farmington, New Mexico.

The *Oil Weekly* of September 2, 1927, contains several papers by Association members. W. F. BOWMAN, of the Associated Oil Company, wrote on "Pierce Junction Salt Dome, Harris County, Texas"; LEW SUVERKROP, petroleum engineer, collaborating with ADDISON YOUNG, geologist, wrote on "Well South of Bakersfield Indicates Accumulation"; JOHN F. WEINZIERL, geophysicist, on "Development of Geophysical Science in Gulf Coast Exploration"; DONALD C. BARTON, consulting geologist and geophysicist, on "Effect of Geophysical Methods on Drilling in the Gulf Coast"; and GEORGE R. ELLIOTT, petroleum geologist, on "California Production Maintained by Deeper Wells."

LESTER C. UREN, professor of petroleum engineering at the University of California, has been made director of research of the Ranney Oil Mining Company (Standard Oil Company of New Jersey).

LOUIS C. ROBERTS, JR., of the Southern Crude Oil Purchasing Company, is situated in the Slattery Building, Shreveport, Louisiana.

L. C. HAY, of the Elmwood Oil and Gas Company, has moved from Eldorado, Kansas, to Tulsa, Oklahoma.

E. F. HAGAN, of the Prairie Oil and Gas Company, moved from Eastland to San Angelo, Texas, last September.

D. DALE CONDIT lives at 321 Dorset Avenue, Chevy Chase, D.C.

PHIL K. COCHRAN, of the Carter Oil Company, has returned from Venezuela and is living at 223 E. 4th St., Apt. H, Oklahoma City, Oklahoma.

IRVING PERRINE, geologist, formerly situated in the Braniff Building, has moved his office to 1621–23 Petroleum Building, Oklahoma City, Oklahoma.

E. K. SOPER, formerly geologist and representative in various foreign countries for the Sinclair Exploration Company, has opened offices in the Roosevelt Building, Los Angeles, California. He is engaged in consulting work as oil geologist, specializing in geology of California and far western states.